DOCUMENT RESUME

ED 448 048 SE 064 344

AUTHOR Tharp, Barbara; Cutler, Paula; Denk, James; Moreno, Nancy
TITLE Legacy of Lost Canyon: A Curious Cave Conundrum. BrainLink: Brain Chemistry.
INSTITUTION Baylor Coll. of Medicine, Houston, TX.
SPONS AGENCY National Institutes of Health (DHHS), Bethesda, MD.
ISBN ISBN-1-888997-47-8
PUB DATE 2000-00-00
NOTE 91p.; Illustrated by T. Lewis. For other books in the BrainLink series, see SE 064 335-338.
CONTRACT R25-RR13454
PUB TYPE Guides - Classroom - Teacher (052)
EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS *Brain; Elementary Education; Hands on Science; *Reading Assignments; *Reading Comprehension; *Reading Instruction; Science Activities

ABSTRACT

Reading Links were created as ready-to-use reading and writing activities that directly correlate to the Brainlink adventure stories. The activities are related to reading objectives common to many curricula and cover a range of grades and ability levels. The book features a story called "Legacy of Lost Canyon, a Curious Cave Conundrum." Students read the book then use the information provided in the text to answer questions contained in the activity packets. A second packet of activities is included on brain chemistry. This packet provides background information for the teacher. A reading section is also included along with activities for students related to the brain. Each activity in the brain chemistry packet contains an overview of the investigation, the science and math skills that are the focus of the lesson, the time required for the activity, and the materials needed to perform the activity. A detailed procedure section for each activity is also included. (SAH)

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Illustrated by T. Lewis

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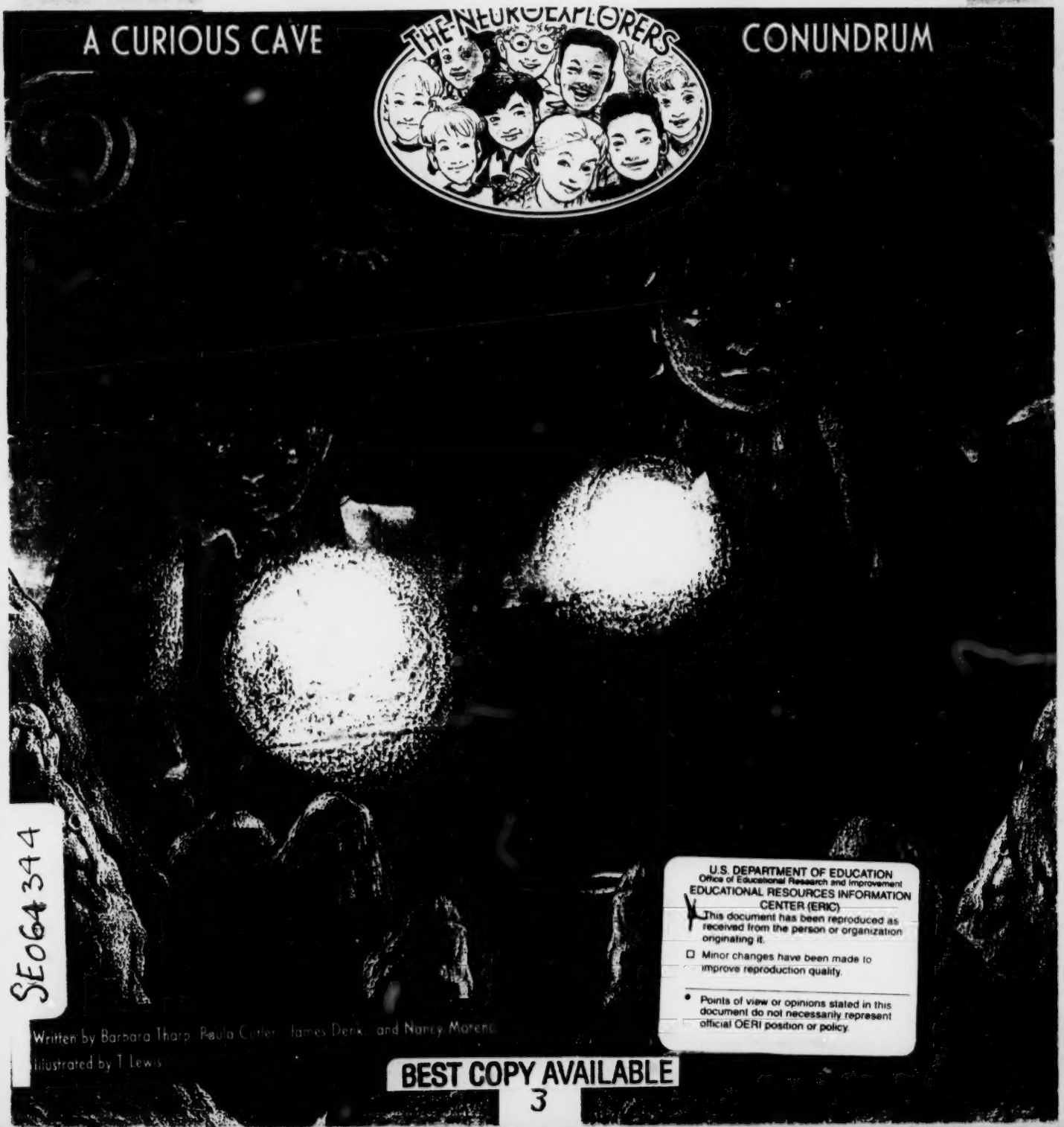
BrainLink
BRAIN CHEMISTRY

Legacy of Lost Canyon

A CURIOUS CAVE

THE NEUROEXPLORERS

CONUNDRUM



Written by Barbara Tharp, Paula Cutler, James Denk, and Nancy Moreno
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BrainLink® Adventures

Legacy of Lost Canyon

The NeuroExplorers™ in A Curious Cave Conundrum

By
Barbara Tharp, Paula Cutler, James Denk and Nancy Moreno
Illustrated By
T Lewis

Baylor College of Medicine
Field Test Version

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Printed in the United States of America

15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

ISBN 1-888997-47-8

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Development of BrainLink® educational materials was supported, in part, by funds from the National Institutes of Health, Science Education Partnership Award grant number R25 RR13454. The opinions, findings and conclusions expressed in this publication are solely those of the author and project staff and do not necessarily reflect the views of Baylor College of Medicine, the sponsoring agency or the publisher.

Production by Martha S. Young

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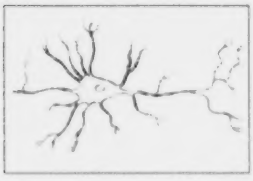
The NeuroExplorers — The Beginning

All Josh Kavil saw was the stop sign. The next thing he remembered was waking up in the hospital. He had been riding his bicycle without a helmet and was struck by a car. His skull was fractured, and his brain was badly damaged.

Some good came of Josh's unfortunate accident. For one thing, he learned never to ride without a helmet. Second, his misfortune was the beginning of the NeuroExplorers.

When Josh's friends came to visit him at Worthington Regional Hospital, some of them became fascinated with the field of neuroscience. On their visits, they met a neurosurgeon, a neurosurgical nurse, a neurologist and a neuroradiologist. These were medical specialists helping patients who had problems involving the brain or other parts of the nervous system.

Neuroscientists study the brain and the rest of the nervous system. The basic building block of the nervous system is the nerve cell, or neuron.



The word "neuron" comes from the Greek word for "nerve." How many words can you find that start with "neuro-"?

It was Kyle Christian's idea to form the club. The members all wanted to know more about the nervous system. They also liked to solve puzzles and riddles and had an interest in investigating some of the mysteries of science.

Since they formed the club, the NeuroExplorers have volunteered at a center for the rehabilitation of brain injury patients, held a Neuro-Science Fair and spent a day in the hospital on rounds with a neurologist. They have learned a lot about how the brain and nervous system work, and they always are looking for exciting things to do with neuroscience.

The Club Members

B.J. Armstrong — B.J. spends a lot of time with her drums. In fact, she carries her drumsticks with her and uses them on any hard surface she can find! She wants to play in a band, but she also wants to be a physician. B.J. has two older brothers who sometimes act as advisors to the NeuroExplorers. One brother is a neurologist at a medical school. Her brothers never liked to use her formal name, Beverly Jane, so they've always called her B.J., and so do her friends.

Kyle Christian — Kyle's father is an archaeologist at Dargate University and often is away on digs. Last year, he took Kyle with him on a short dig in Belize. Kelly, Kyle's sister, sometimes does things with the NeuroExplorers, although some of the members feel that she is a little young for the club. Kyle likes to read science

fiction books and play computer games. His hobby is memorizing fascinating trivia.

Lakeisha Crawford — Lakeisha wants to be a chess grandmaster, so she carries a pocket chess game around with her. She often thinks about things in terms of chess problems, and she has developed a good memory. She also likes to play other games and sports. Karate lessons are her latest passion. Lakeisha has a little sister who has epilepsy.

Isley I and Isley II — Identical twins, Isley I and II (even their parents don't call them by their actual first names) are always kidding each other. They both love sports and play soccer, baseball and basketball. Isley I collects baseball cards and has a 1954 Mickey Mantle in good condition. Isley II holds the record for consecutive basketball free throws in his school. Their father, a bird-watcher, got them interested in science by reading to them from the notes of Charles Darwin.

Josh Kavil — When Josh recovered from his head injuries, he couldn't wait to join the club with his friends. Josh has always liked science, because he loves to figure out how things work. He also loves animals. He has a pet lizard named Scooter, a snake named Slim, two dogs and two cats. After his experience as a patient in a rehabilitation center, he decided he would like to be a physical therapist when he grows up.

Max Miller — Max has been friends with The Brain since they were babies, and that's why he understands him so well. They spend most of their time together. While The Brain reads, Max often works on models of boats and planes or builds things with wood. Max became interested in neurology when his grandfather had trouble with his memory and was diagnosed with Alzheimer's disease.

The Brain — When Antonio Velasquez-Ruíz, alias The Brain, was a toddler, he was very quiet and never tried to talk. One day he suddenly began speaking in complete sentences. Since then, he has been known as the smartest boy in town. The trouble is, only his best friend can understand The Brain's big words and long sentences. The Brain reads a lot, but his most-used books are a very fat dictionary, a set of encyclopedias, and Gray's Anatomy.

History Lesson

Squiggles, stars and arrows — who was copying whom? As Lakeisha, one of the NeuroExplorers, looked from book to book and site to site, she could tell something strange was going on. The picture in her history book was of a famous, 4,000-year-old cave drawing in France, and she knew she had seen a similar picture in her art book, but that image was from Tanzania. While searching the Internet, she had found more cave paintings — or pictographs, as archeologists called them — and the similarities were amazing. France, Tanzania and Texas?

Early cave-dwelling people, thousands of miles apart, and in different centuries were trying to tell us the same story! Lakeisha had to share this confounding puzzle with her friends.

Her opportunity came in the after-school session of the NeuroExplorers' science club. Over the last three years, the club had had some exciting adventures. It was time for another! Mr. Lopez, the club sponsor, started the meeting by asking the members for ideas for the summer's investigation. He reminded the NeuroExplorers that this would be the last meeting of the school year. Lakeisha immediately spoke up.

She explained her confusion. "How could this be?" she asked as she began to pull out pictures. Her friends all gathered around to have a look. B.J., her best friend, immediately saw a pattern.

"Look at the geometry," said B.J. "The shapes have a definite similarity. Most of the lines are parallel. And . . ."

Isley I and Isley II, twin sports fiends, took one look at the pictures and complained that they'd much rather study the physics of basketball, adding that these drawings were just old artwork, not science.

"On the contrary," spoke up Antonio, also known as The Brain, "this is a fascinating conundrum of a scientific ilk. Archeologists study the

renderings of indigenous people to derive vital cultural clues."

"He's saying," his best friend and interpreter, Max, interjected, "that this actually is an interesting question. Scientists, who study material remains of past cultures, learn a lot about ancient times from the artwork the people left behind."

"But what's so important about a bunch of old squiggles on a cave wall, especially geometric squiggles?" asked Josh.

"That's the whole point," insisted Lakeisha. "I want to know what these drawings mean."

Mr. Lopez interrupted, "I think Lakeisha's question merits some thought."

"Terrific!" groaned Isley I, with a definite attitude. "Now all we have to do is get to France, Tanzania or Texas."

"You know," continued Mr. Lopez, "I haven't thought about this in years, but the dam on Rocky River just above town quite curiously ruptured this spring. There's a good possibility of investigating a Native American site right here in our own backyard."

"Yeah, I heard the dam was supposed to last forever and it barely made it thirty years," said B.J. "Of course, that seems pretty old to me, but what do you mean, 'curiously'?"

"And what do you mean, 'Native American site'?" asked Josh. "I've never heard any stories about Indians in this area."

"Scientists investigated after the dam broke. They found it could have been damaged intentionally, but nothing ever came of their report," explained Mr. Lopez. "In fact, it seemed to be hushed up quickly . . ."

"But I digress." he went on. "What you all need is a little history lesson!"

"First math and now history. What's next? English?" said Isley I with a frown.

Mr. Lopez ignored Isley I and explained that before Coslett Dam was

built, there were limited excavations of caves that pockmarked the canyon walls on either side of Rocky River. Archeologists from nearby Dargate University were dismayed when the state water commission decided to locate their next watershed project in an area that would quickly flood access to this research site. Despite protests from the University, Coslett Dam was built in 1970. Access to the archeologists' project was flooded by millions of gallons of water.

"But since the high water is gone after the dam break," said B.J., Lakeisha's co-conspirator, "the entrance to that site could be uncovered again. Let's go!"

"Hold on," Mr. Lopez cautioned. "There's a lot to consider." He reminded the NeuroExplorers that the caves had been unreachable for over 30 years.

"However," he added, "I seem to recall that one of the lead scientists on the research team wrote several articles about their work. Her name was Dr. Sallie Hazelton, I think. Why don't you students do a little investigation and gather some background information?"

Walking in Footsteps

Ms. Kay Ching, the librarian, looked up from her desk and found eight pairs of eyes peering intently at her. After hearing the NeuroExplorers' request, she answered, "Yes, I have heard about Dr. Hazelton, but that was a long time ago. What do you need to know?"

"We need to know everything about the university research site flooded by Coslett Dam," said Lakeisha. "On the Internet, we've found Dr. Hazelton's email address and references to articles about her team's preliminary findings, but we need the articles themselves. We want to see them before we write to her."

Ms. Ching searched the archives and returned a few minutes later with

two old, bound volumes of archeology magazines and microfiche containing relevant newspaper articles. She gingerly handed these materials to the group, cautioning them to examine all the materials carefully and to return them before leaving the library.

Kyle slowly opened the front cover of the first magazine as the others looked on curiously. The first article was entitled:

Indigenous Peoples of Rocky River: Preliminary Studies, 1969–1970
By Sally Hazelton, Ph.D.

BINGO! The search was on as the NeuroExplorers began to read. The silence was so intense you could almost hear their eyes moving across the pages.

Dr. Hazelton's sketches and descriptions mesmerized them.

Max squeezed in closer to get a better view as Kyle slowly turned the pages. Sketches of animals, jewelry, bones, tools and pottery astounded the NeuroExplorers. One drawing in particular caught their attention.

Lakeisha gasped, "LOOK! Those are the same shapes — squiggles, stars, lines and arrows — that I showed you on the other cave paintings!"

"Consider the abstruse patterns, the intricate, undulating lines, the convoluted, yet strangely harmonious depictions of these pictographs," said The Brain.

Without hesitation, Max came to the rescue. "The Brain is saying that these cave drawings have unusual patterns and a complex arrangement of wavy lines and irregular shapes that seem to have a purpose."

"This is interesting," said Josh, "but I'm still trying to figure out what these weird pictures could possibly mean. What do you guys think?"

Lakeisha said, "I'm not sure, but right below the sketch Dr. Hazelton wrote, 'Shaman hunting magic.' We have so much to find out! Like, what's a shaman?"

At this point, the NeuroExplorers divided up the materials and read voraciously until Ms. Ching told them the library was closing. After reluctantly returning the materials, they all began sharing what they had

learned, and what they thought it all meant.

"Wait!" yelled Kyle. "One at a time!'

Lakeisha began, "A shaman was a spiritual leader in the community. He had many responsibilities, including healing the sick, communicating with the spirits who they believed ruled their world, and escorting the dead to the after-life. Apparently, people across the world have had shaman for thousands of years."

"According to Dr. Hazelton's article," added Max, "there are remnants of that past right here in our midst. She discovered the remains of a civilization that was possibly over 1,000 years old!"

B.J. chimed in, "Wow, I feel like we've been walking in her footsteps today! We have to meet her!"

Overload

"What a stroke of fortune," wrote Dr. Hazelton, in response to the NeuroExplorers' email query. "I have been planning a trip back to my first research site ever since I heard about Coslett Dam's collapse. I would be delighted to meet with your team on my arrival back in River City! I'll meet you in front of the University Library at 3:00 p.m.!"

The group gazed at the message printed from Mr. Lopez's computer one more time while they waited in front of the Library. As the giant clock on the Science Building struck 3:00, up strode a petite, grandmotherly-looking woman in overalls and running shoes. She introduced herself as Professor Sallie Hazelton. She didn't look like the bookish scientist the NeuroExplorers had expected!

Soon they were deep in discussion. The students had so many questions and Dr. Hazelton had so many answers. But where to begin? They all sat on the edges of their comfortable chairs in the library

conference room, fascinated by the spunky, quick-witted Professor. They quickly discovered that she was not only an archeologist, but also an accomplished spelunker and a former champion rodeo roper. What an adventure this could be!

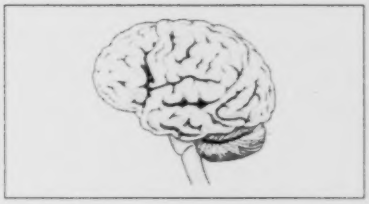
After hearing all their eager questions, Dr. Hazelton smiled and said, "It's always best to start at the beginning."

Thus began the engaging story of how this scientist became involved in archeology and, more specifically, discovery and investigation of the Native American dwellings in her own area. Dr. Hazelton explained that as a child, she had played along the banks of Rocky River, where she found and collected all kinds of interesting bits and pieces that caught her eye. She later learned that her finds were Indian relics, but she couldn't find any other information about them.

Inspired by her interest, she studied archeology in college, where she continued to wonder about her finds around Rocky River. Finally, after completing several digs elsewhere, she got funding from the Native American Heritage Society to conduct her own investigations here in 1969.

She and her team of scientists began work in an area where the canyon's high walls were riddled with what looked like ancient cave dwellings. They started their excavation on a ten-foot-deep midden of a lower level cave. There, they unearthed several ancient items that told a fascinating tale about people who had lived there more than 1,000 years earlier.

The brain is the most complex organ in the body. It is responsible for emotions, thoughts, memory, movement, the senses and automatic functions such as breathing. The brain communicates with the body through the spinal cord which connects with a network of nerve cells throughout the body.



The brain has three parts:

Brainstem – governs automatic functions such as breathing and heart beat.

Cerebellum – helps muscles work together and stores programs for well-learned movements (like riding a bicycle or playing the piano.

Cerebrum – responsible for thinking, learning, remembering, the senses, emotions and movement that you think about

At this point Isley couldn't stand it anymore. He asked, "What's a midden? What did you find? Where is the stuff? My brain is on overload."

As the rest of the NeuroExplorers glared at Isley I, his twin brother teasingly said, "And what part of your pea-brain would that be . . . Your cerebellum, cerebrum or brainstem?"

Professor Hazelton curtailed the banter by responding patiently, "A midden is a garbage dump, so to speak. It's where the people living in the caves would have placed their refuse. Among our finds were pottery shards, broken arrowheads, tools and animal bones."

Then she resumed her story. The archeological team knew that where there was a midden, there would be dwelling areas. Another cave above their initial site was particularly exciting because of the mysterious drawings on its walls.

Then, just about the time they were ready to move to this new cave, Coslett Dam was completed. Rocky River backed up in the canyon, and the rising water made it impossible to continue the excavation. Within days, the lower site flooded and the water continued to rise like a giant filling his bathtub! The scientists had argued with the authorities for over a year to stop the dam project, but despite evidence of the historical significance of their work, the state water commission proceeded with the construction.

Now that the dam was gone, Dr. Hazelton was eager to resume her work. After she finished her story, the NeuroExplorers began talking all at once. Her enthusiasm and energy were contagious. Without exception, the friends felt a rapport with her and were inspired to join her quest. She welcomed their assistance for the summer months. She already had spoken with Mr. Lopez, who told her of their interest and the success of their previous adventures.

The Trail

The NeuroExplorers were excited about visiting Dr. Hazelton's research site and about using the training they'd received at the camping and trekking classes they'd taken earlier in the year. As they assembled for the

The brain communicates with the rest of the body through the spinal cord and a network of neurons. Neurons are specialized cells that send messages in one direction. Neurons receive messages on branches called dendrites. The messages are carried along the cell membrane as an electrical charge. They are passed to the next neuron by a special chemical called a neurotransmitter. The neurotransmitter moves across a tiny gap between cells and attaches to a special receptor in the next neuron.

Neurotransmitters can signal neurons to continue sending the message (called "firing") or they can keep neurons from firing.

beginning of their hike, Professor Hazelton, whom the students dubbed "Dr. H.,' called for a gear check. Each student was equipped with a day-pack holding food, water, a heavy-duty flashlight and a climbing rope. Kyle also carried a small first-aid kit in his pack.

They felt like they had landed in a different world. The terrain began to slope downward as they approached a canyon cut deep into the ground, with a small river in its belly.

"Going down into the canyon will be a little tricky," Dr. Hazelton cautioned. "Remember the plan we went over last night. As the trail gets steeper, walk carefully and stay with your buddy."

The NeuroExplorers already had paired off with partners for this adventure: Lakeisha and B.J., The Brain and Max, Kyle and Josh, and the two Isleys.

Carefully, they began their descent into the canyon. They walked single file, winding along huge rocks as the trail led them down toward the river.

"Did it occur to anyone else that we're just like a string of neurons, working together here?" Josh asked as he followed Kyle.

"Astute observation!" The Brain replied, slightly out of breath. "How gratifying that you ponder neuroscientific principles in these potentially precarious environs."

"Nice going, Josh," Max said. "You've pleased him, thinking about neuroscience in these challenging surroundings."

The path narrowed as it led the group onto a ledge in the middle of the canyon wall. Then, abruptly, it ended. Ahead, a huge boulder blocked the path. On one side was a rock wall looming above them, and on the other side, sheer nothing.

Max and The Brain approached the huge rock, looking for a another way. "Look up! It appears perpendicular — to wit, quite a vertiginous escarpment," the Brain mused, rubbing his chin in thought.

"What?" yelled the NeuroExplorers behind him.

"He said it's straight up from here, and it looks pretty impossible," Max explained. "I guess we'll have to turn back. There's no more trail."

"Oh, we can go on," Dr. Hazelton assured them. "We can climb up to natural ledges in the canyon wall, just as the Indians did, using toe-holes they carved in the limestone rock walls."

Suddenly, Isley II shouted, "My brother is gone! I think he slipped through this crack in the rock!"

He yelled into the small opening, "Isley, Come back here! Are you okay? Are you in there?" As he was calling, Isley II carefully slipped through the small hole to search for his brother. He found him just below.

"I was going to come back and get you," said Isley I. "I think I found a way up!"

"You know we're supposed to stay together!" chided his brother. "No more of this disappearing routine or you'll be out of here." Then Isley II turned in surprise as the rest of the gang appeared behind him.

"How did you get here?" he asked in amazement. Apparently, Isley I had, indeed, discovered just the route they needed.

A narrow path led the adventurous group up from the river to one of the many small shallow caves that seemed to honeycomb the canyon wall. From there, it continued out onto a trail along the ledge in the canyon.

The steep walk was often treacherous, yet beautiful. As they made their way up toward Professor Hazelton's first excavation site, the group peered up and down the canyon walls. The view was breath taking. Far below,

Hormones have vital functions in mammals. Unlike the chemical messengers between neurons, hormones can have wide-reaching effects on many different tissues in the body at the same time. Hormones, which are chemicals that circulate in the bloodstream, act as messengers to the nervous system and to other parts of the body. Hormones only can act on cells that have the right kinds of receptors.

In times of danger, a number of non-essential bodily functions, such as digestion, are shut down. Other systems are "revved up" in anticipation of needing to fight an enemy or to run away. This reaction is partially controlled by the hormone adrenaline (epinephrine). You may have felt its effects at one time or another. They include a pounding hear, sweaty palms and a feeling of nervousness.

they could see huge boulders stacked at the edge of the river like stepping stones for a giant. They were enormous, yet perfectly balanced in the strangest of ways. Nature's symmetry was on display! The group had hiked into the canyon and now was up on its walls, already high above the river!

As everyone crept along the edge of the precarious ledge, Dr. Hazelton spoke from the lead, "Be careful! Hold onto the rock. There's water coming from somewhere above and the ledge is slippery as slime!"

Each NeuroExplorer, in turn, passed the message on down the line. Before the message got to Kyle, the last person, a panicked shriek echoed off the canyon wall. Kyle had lost his balance and was slipping down a slope in the ledge. Josh instinctively grabbed Kyle's shirt and the quick-thinking NeuroExplorers immediately joined hands to form a human chain to pull Kyle back up onto the ledge.

"Critical, timely firing of our synapses has forestalled a calamity!" The Brain yelled with excitement.

"He said that our quick thinking and action prevented a terrible accident," Max translated for the others, who looked at The Brain with annoyance. Then they looked at Kyle, who was safe, but visibly shaken.

"WOW! You saved my life!" said Kyle with a sigh of relief and disbelief. He sat on the ledge, catching his breath. "Whoa! My heart is really pounding!"

"My heart is pounding HARD!" Josh said. "That adrenaline sure kicks in when the going gets rough, doesn't it?"

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Discovery

"That was too close for comfort," sighed Dr. Hazelton. "I could never forgive myself for losing one of you in the already Lost Canyon. We're almost at the first cave I explored. Let's get there and break for lunch."

B.J., ever the drummer, slapped a drum roll with the palms of her hands on the rock wall beside her in agreement, as the athletic Isley twins high-fived. Next to a good mystery, food was their favorite thing! They all carefully continued up the path, toward the cave.

When they reached the promised cave, Lakeisha said, "This place is gorgeous, but it sure is hard to reach. Do you really think people lived here thousands of years ago? It seems impossible!"

The Brain replied, "There is a preponderance of evidence to suggest that an indigenous population existed in these spectacular, albeit inhospitable, environs, Lakeisha."

"Max! Translation!" the Isleys demanded simultaneously.

"In brief, The Brain is saying that, according to Dr. H.'s preliminary findings, Native Americans did live around here," Max explained.

"Exactly!" exclaimed Dr. Hazelton. "My research in Lost Canyon was just beginning to show not only that Native Americans inhabited these caves, but how they lived." As she bent down to check out something, she said, "And here could be more proof!"

"What is it?" the NeuroExplorers cried in unison while crowding around Professor Hazelton.

"I can't tell for sure without excavating it completely, but it looks like a . . ." Professor Hazelton's voice trailed off as she carefully unearthed a small tool.

Kyle spoke up. "It's a pickax — one like my Dad uses in his archeological digs."

"Yes," said Dr. H. "it may be one we unintentionally left behind. My crew and I had to abandon the cave abruptly when they began dynamiting for the dam."

The brain and nervous system need many different kinds of raw materials to carry out activities within cells and to manufacture messengers that communicate between neurons.

A diet that includes enough energy sources from whole grain breads and cereals, as well as plenty of fruits, vegetables, lean meats or other protein sources, and low-fat dairy products, provides everything the brain needs to perform at its best.

Dr. H. was pumped! All the old feelings about this cave came flooding back. As the NeuroExplorers hungrily devoured their lunches, they watched with interest as she moved slowly about the cave. She inspected the cave's floor and then its walls with a cat-like curiosity. She explained that she and her crew had completed only the initial stages of their exploration of the cave.

"Almost from the start, this cave was an ancient treasure trove for lots of reasons. Yes. This looks familiar. Let's see . . ." she almost whispered.

Her cursory investigation led her to the cave's interior back wall, at which point a look of horror crossed her face.

"Where is it?" she cried, frantically searching the walls with her light. "I know this is where I found the shaman drawing! It's been destroyed! Cut right out of the wall! Vandalized!"

"You mean the shaman cave drawings in your book?" asked B.J. "The ones that have the squiggles and stuff?"

"HAD! It's GONE!" a shocked Dr. Hazelton cried as she frantically shined her light all around the wall. "My beautiful pictographs! Who could have done this? Who would have done this?"

The NeuroExplorers all stood staring up at a scarred rock wall. Rectangular gouges were cut out of the surface. It was a devastating sight. The only vestiges of an irreplaceable work of art were a few remnants of painted figures. No one dared move or turn on a flashlight or say a word. They just stared as Professor Hazelton stood stone still, in near shock, in

front of the scarred rock wall.

In only a few hours, they had found what had been lost to the Professor for 30 years. She had led them almost directly to the spot, even though much had changed in the canyon due to years of rushing water and floods. It seemed inconceivable to them all that Dr. Hazelton's amazing discovery had been permanently removed.

Shaman's Cave

At first they all were too stunned by the missing pictographs to notice, but then, creeping up from somewhere, they heard strange moaning sounds that began to echo quietly through the cave. The sound started softly and slowly, increased and then stopped.

They looked at each other. What? . . . Someone or something else was in the cave! Then a loud shout cut the silence. It was Isley I. Once again, he was nowhere to be found.

"Isley, this isn't the time for one of your pranks," yelled his twin brother and hiking partner. "Where are you?"

There was no answer. The moaning had ceased. It was replaced by a strange pinging sound, coming from another direction. The cave echoes increased their confusion! "Isley, where are you?" yelled Isley II again, even louder.

Professor Hazelton rallied from her stupor. "Don't panic. We can do this! I know there's only one way into this cave and he has to be around here somewhere!"

Professor Hazelton called out for Isley I, but there was no answer, only her voice falling off in echoes through the cave. They all grew deadly quiet, straining to hear through the silence. After what seemed like an eternity, they heard a small voice that seemed far away. At the same time, from

another direction, the pinging sound resounded once again through the cave.

Finally, came the unmistakable, muffled voice of Isley I. "I'm down here! Guys! I'm down here!" he yelled.

Everyone began looking frantically about the cave, but there was no "down here," just a rock-strewn dirt floor all the way to the back of the cave. With flashlights illuminating their way, the group spread out. They searched up and down the walls and around the edges. Isley I was calling from somewhere, but where?

Then, finally, not far from the missing pictograph, Lakeisha discovered a hole in the cave floor. It was a small opening not much larger than a backpack, near the very edge of the cave's sloping back wall. It looked like the earth had just pulled away from the wall at that spot, leaving a hole large enough for one Isley to fall through! It seemed impossible, yet that's where Isley's voice was coming from.

Lakeisha dropped to her knees, leaned forward, put her head in the space and called to Isley, "Are you really down there?"

"Yes, I'm really down here! Be careful, Lakeisha!" Isley tried to warn her.

"What are you doing down here, Isley?" yelled Lakeisha, just as she fell through and landed on top of him with a thump! She groaned in disbelief.

"Hey, I broke your landing, didn't I, so what's the problem?" asked Isley. "I stepped onto a big rock close to the wall there, to get a better view of the damage. The rock wobbled a little and the whole thing collapsed! I slid down here just like you. What a fantastic rock slide!"

"It was quite a ride, but I don't think we can repeat it in reverse! It's too steep," said Lakeisha. "Now what are we going to do?"

They both began to call from the dark hole in unison. "We're down here!"

Professor Hazelton was relieved when she faintly heard Lakeisha talking to Isley from across the cave. She followed the direction of their voices, but when she approached the area, no one was there. She waved her light all around and finally caught sight of the hole in the cave floor.

Bracketing the opening with her feet, she shined her light down into the hole. This was a surprise. She could see Isley I and Lakeisha, and they seemed to be in what looked like another cave. How could this be? As far as she knew, these caves never had anterooms, or connected chambers deeper into the walls of the canyon. Nevertheless, Isley and Lakeisha appeared to be in a connecting room of the shaman's cave!

While Isley and Lakeisha waited for the others to rescue them, they could only wonder where they were. The floor they were lying on was smooth and cool. They both had lost their flashlights when they fell and there was only a tiny ray of sunlight shining down from high above. Slowly, as their eyes became accustomed to the dark, they could see some faint outlines on the wall closest to them. The lines looked like a jumble of frenetic shapes!

As the Professor called down to them, the others arrived on the spot. Dr. Hazelton quickly tried to explain what must have happened as she began lowering her rope into the cave for their descent.

Supernatural Moment

One by one, the six remaining NeuroExplorers used the rope to rappel down to Isley I and LaKeisha. Once they all reached the bottom of the rock slide, Kyle began to wave his light around.

"This is a pretty big cavern," he said, astonished. "I'll bet someone used this place long ago. It could be a neat place to hide out."

"Well, leave it to my baby brother!" said Isley II, grinning at Isley I. "Guess you really are an explorer. Maybe we should call you a CaveExplorer instead of NeuroExplorer! Now, what possessed you, and are you okay?"

Isley I proceeded to explain how he, and then Lakeisha, had fallen into the adjoining cavern. When Professor Hazelton arrived, she wasn't a bit

angry. After all, it had been an accident, not a prank! In fact, she was excited that Isley and Lakeisha had discovered another chamber to explore.

And this place was big, really big! The room picked up every word and bounced and bounced and bounced it.

After the fright and excitement, Professor Hazelton asked the group just to sit down for a minute and take stock of the situation. "Is everyone here? Is everyone okay? And most of all, what is this place?"

As usual, everyone began to talk at once. All the words formed a disjointed, cacaphonous echo that bounced around the room and could not be understood.

The NeuroExplorers were full of questions, but no one could be heard over the others. "What are? Who is, where, how . . . ?"

With a sharp whistle, Professor brought them all back to attention. She moved to the center of their circle, and everyone watched silently as she lifted her light high and slowly turned around the room. They were totally awed, left speechless by the haunting, beautiful, ancient art that surrounded them. They definitely were in a shaman's cave. Everything they had read and everything the Professor had explained was now encircling them. The cave was enormous — over 50 feet across and almost as long — but just like in Lakeisha's pictures, the walls told the story.

It was an almost supernatural moment for them. The colors, the shapes, and the mysterious aura that surrounded them spoke of a different world. It was a history book without words!

There were paintings on every wall. Professor Hazelton was scanning one in particular with her light. She asked all the NeuroExplorers to shine their lights on the same wall. They illuminated a huge mural. It looked as big as a billboard! The wall painting featured six humanlike figures linked by some sort of rope, along with a variety of animals, arrows, squiggly lines and dots!

"Pictographs, rock paintings crafted by inhabitants of this canyon," exclaimed The Brain in obvious appreciation.

"Look at those crazy lines and wild pictures! I wonder what they could mean," commented Max.

The Brain contorted his face in deep thought. "I fear none but Professor Hazelton is qualified to decipher these enigmatic creations. However, I posit this ancient rampart is a priceless art galley."

"You call this art?" said Max. "It looks like some kind of strange graffiti to me!"

"On the contrary," disagreed Professor Hazelton excitedly. "Graffiti often is considered destructive. When a person writes on a wall or structure without permission, it is considered graffiti. But this is rock art, fabulous pictographs."

Many chemicals have powerful effects on the nervous system. Some drugs mimic the effects of chemical messengers (neurotransmitters) between cells. Others interfere with the manufacture or recycling of messengers. Cocaine, for example, interferes with the uptake of a neurotransmitter that causes certain neurons in the brain to "fire."

Hallucinogens

"This truly is a find, a pristine shaman's cave," declared the Professor. "Do you see that small circular hole way up there in the ceiling? See where the light is coming through? Well, that hole once served as a smoke vent for fires that the shaman burned just about where you're sitting right now."

She continued as the NeuroExplorers listened with rapt attention. "Evidence suggests that rock art of some tribes was tied to the spiritual activities of the community. The community gave the shaman, its spiritual leader, permission to paint on the rocks and leave a historical inscription, a record of significant events. What these ancient pictographs mean and why they were made is not well understood. We believe that much rock art was inspired by religious beliefs. Also, these paintings often are thought to represent visions induced by hallucinogenic drugs taken by the shaman to carry them to the spirit world."

"Neuroscience most indubitably is omnipresent through the annals of time," muttered The Brain, almost to himself.

Many mind-altering drugs that are abused by children and teenagers lead to permanent changes in the brain and other parts of the body. Marijuana can damage memory regions of the brain, in addition to affecting coordination and the senses. Heroin changes the way nerve cells in the brain receive and process messages. Inhalants, which are taken up by fatty tissue in the body, can damage the fat-containing insulation (myelin sheath) on nerve cell axons. LSD contributes to the development of chronic mental disorders. Alcohol damages a number of organs, including the liver and brain and is a major contributing factor to automobile accidents. Nicotine, in tobacco, is a very addictive substance — however, the greatest health risk comes from other chemicals in cigarette and cigar smoke that are linked to several different kinds of cancers.

The others were too wrapped up in their discovery to ask, but Max translated anyway. "Neuroscience is everywhere, and has been throughout history."

Finally, the excited and exhausted group took a collective deep breath as Professor Hazelton lit the lantern from her day-pack. The room began to glow. It was magic. They were transfixed.

"So many of the shapes are the same. It's more than amazing," said Lakeisha in whispered respect. "They look so much like the pictures in my art book."

"According to research, these shapes are found in many cave pictographs due to the shamans' common experiences. Many cultures believed that to commune with the spirit world, one must enter a trance-like state. This state of mind often was brought on by the use of hallucinogenic drugs. Of course, different cultures may have used different drugs, but the effects on the brain apparently were very similar. Quite often, as you can now see for yourself, the geometric shapes, and even the colors, were similar, even in paintings done continents apart."

"Wait a minute," said Isley II. "Are you telling me they had those hallucinatory drugs back then? I thought those were invented in the '60s.

"Sure they did. Today we hear about drugs like marijuana, heroin and cocaine, but they used drugs way back in history, too," Dr. Hazelton explained. "Some of the drugs we use today may be very much like the ones early people used. Of course, life was very different long ago and even today we have only theories about what really happens to the brain when certain

drugs are used. Now we know much more about drugs, but we're still a long way from understanding them completely. We DO know they're dangerous, and early people didn't know that."

Isley II said, "I take drugs every day . . . for my asthma."

"Yes," said Professor Hazelton, "there are many good uses of drugs for treating medical conditions."

"Like pain relievers," Lakeisha suggested.

"And anesthesia," said Max.

"What about drugs doctors don't prescribe, like alcohol and marijuana, and even caffeine and cigarettes?" B.J. asked. "Lots of people use them, too. How dangerous are they?"

"They can be very harmful," answered Professor Hazelton. "People who choose to use dangerous drugs are risking everything. These days we know drugs affect the brain, and we're working to understand more and more about exactly how."

"That's amazing," said Isley II.

Studies on how chemical messengers work within the brain and nervous system hold promise for unraveling many basic questions about the actions of drugs and the causes of some diseases. Almost all drugs that influence the way the brain works do so by altering the transmission of chemical messages. This can have important medical applications for the treatment of severe pain or illnesses, such as schizophrenia or depression. Some medicines used to treat depression, for example, act on chemical messengers that are involved in regulating sleep and body temperature. Morphine, a potent pain medication, mimics the effects of a natural chemical messenger involved in brain pathways for minimizing pain and producing a sense of well-being.

Vision Quest

Professor Hazelton resumed her shaman discussion, and the

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NeuroExplorers gave their complete attention. "The shaman's supernatural trip was called a vision quest. The shaman conducted this ritual to obtain, and sometimes manipulate, supernatural power."

"After years of training and preparation, a person finally would become a shaman by going on his first vision quest, sometimes accompanied by another shaman and sometimes alone. In either case, he would leave his community and travel to a known vision quest spot — often a rock art site, like this one, believed to be inhabited by supernatural spirits. It might be a distant location or it might be relatively close to his own village, but the quest always would occur when the other members of his tribe or clan were not around."

"The shaman would pray when he arrived at the vision quest site and then seat himself in front of a chosen rock. He would remain at this spot without food, water or blankets for a number of days, praying and meditating — usually until he had a vision. Often during this period, he would use some type of drug. Depending on the area, the drugs used might have included native tobaccos and peyote. These are strong hallucinogens that aided the onset of the vision."

"The shaman's visions were believed to represent an entry into the supernatural world. The images you see on these walls most likely depicted the events and spirits the shaman experienced while in this sacred realm. The art was greatly influenced by a shaman's way of life and personal experience, but because all humans have similar mental systems, some aspects of all shamans' visions were the same! The shaman left the pictures of his visions on the rocks to preserve them for posterity. The designs were made at the conclusion of the shaman's vision quest, after he had stopped hallucinating but before he returned to his village."

The NeuroExplorers' intense concentration was broken when they again heard the strange banging sound coming from somewhere nearby. The echoes cut through the silent canyon like a knife!

"Sensory overload," blurted The Brain. "Following such acute cognition over the Professor's extraordinary account, this clamor is a heavy mallet on my tympanic membrane!"

Everyone else covered their ears, too. No translation was necessary this time.

"If that's what I think it is, I have to stop them," said Professor

Hazelton, as she grabbed the rope and used it for leverage to pull herself back up the rock slide.

"Whoa, where are you going, Dr. H.?" called Kyle. "What are you talking about?"

"No time to explain," Professor Hazelton called back. "I have to stop them!" With that, the agile Professor was up the rock slide and gone.

The NeuroExplorers quickly took stock of their improbable situation and went into action. Wherever Professor Hazelton was going, they were going too. They ran as one across the cave toward the rock slide. Then there was nowhere to go but right back up! They crawled, one at a time, grabbing the rope as they scrambled their way up the smooth rock slide.

"This isn't nearly as easy as Dr. H. made it look," said B.J. "She's some kind of woman!"

They all ran through the first cave and out onto the narrow ledge where they had entered. Professor Hazelton was nowhere to be seen. The winding trail back down to the belly of the canyon was obvious now that they had traveled this far, but to go beyond that seemed more of a challenge.

Following the Bang

They all looked for Professor Hazelton, eyes scanning up and down the canyon walls. However, they saw nothing but rock, with a few hardy mountain goats on the opposite side.

"Quit talking and listen! That banging sound has started again and I think it's coming from up there," said Kyle, pointing his finger directly up the sheer rock wall.

"Where else could she have gone? Why would she leave us? It has to be

about the banging," said Lakeisha, looking around nervously.

"I say we go up," said Isley II. "She might need our help!"

"Easy for you to say," said B.J. "Just how do you suppose we get up that sheer cliff?"

"Like this," called Isley I, as he began his ascent, toehold to toehold. "It's a piece of cake — follow me!" The NeuroExplorers were off immediately, slowly snaking their way up the canyon wall.

After eight challenging toe/fingerholds, they all reached another natural ledge, but Professor Hazelton was still nowhere to be found. Isley I gave them all a hand up onto the ledge, and the NeuroExplorers once again were navigating a narrow precipice over Rocky River, now far below. They continued in careful concentration as the trail led steeply up the canyon wall. The banging grew louder as they made their way around a huge boulder.

Suddenly, the group heard an earth-shattering shout. They almost tripped over one another as they jammed to a quick halt. The trail led directly into another huge cave. Dare they enter this deep, dark cave without Professor Hazelton?

"We've come this far. Why stop now?" asked Isley I excitedly. "Besides, it's not very cozy out here on this ledge, either. I say we follow the sound. That's where we'll find Professor Hazelton."

The NeuroExplorers cautiously entered the cave, flashlights on. Three steps in, there was another loud cry.

"I'm not so sure I want to go on with this," whispered B.J. "We really don't know if this is about Dr. H. There could be a mad man in there. It sure sounds like it!"

"Well, remember, there was no other way to go. It has to be her and she needs us," said Kyle.

They sneaked forward, one quiet step at a time, listening for anything that might tell them what was going on. But there was no sound. Finally, they saw a faint halo of a light and two figures ahead. They slowly moved forward to get a better look.

The Culprit

The scene inside the cave stunned the NeuroExplorers! They saw tiny Dr. Hazelton standing over a burly man.

Lakeisha yelled, "Professor Hazelton, it's us — are you okay? What's going on?"

"I came up on him from behind and surprised him," the Professor called, still a little out of breath. "I used my rope to lasso this despicable character. He's the culprit who was cutting off the precious pictographs. I caught him red-handed! I can't let him escape — help!"

The NeuroExplorers charged at the bellowing man on the ground and quickly tied him up using their climbing ropes. When they turned him over, the Professor looked shocked.

"Why, it's Jeb Hunnicutt!" exclaimed Professor Hazelton, astounded. "You grew up in these parts, just like me. You once were a promising geologist and look at you now. Destroying history . . . I really can't believe it!" She paused for a moment before continuing. "Well, you won't be destroying any more of these precious pictographs, Jeb."

"But why would he even do it?" asked a confused Lakeisha.

"He's the only one to know for sure, but I suspect ol' Jeb has a market for these relics, even if they come in pieces!" said Professor Hazelton. "The hammering sound was his chiseling away at the rocks, removing the pictographs, piece by piece as they broke away from the wall. It looks to me like the dam didn't break by accident. Jeb was able to start his thievery suspiciously soon after the water level dropped."

"Now what do we do with him?" asked Josh.

The group needed help getting Jeb out of the canyon, so Professor Hazelton called the authorities on the cell phone she pulled from her day-pack. Then, she sent the Isleys on a scouting trip. They were only 40 feet

from the top of the canyon. There had to be another way out. They couldn't begin to imagine getting Jeb out the way they came in. It was impossible unless he was untied — and that wasn't an option.

After a few minutes of brainstorming, they heard a whirling sound outside. The rescue helicopter was overhead and the Isleys were flagging it down!

"They sure got here in a hurry," said Kyle.

"It's a good thing, too," added the Professor. "The more I think about what Jeb's done, the more I want to leave him tied up in this cave!"

Everyone laughed — except Jeb. Within a few minutes, the flight crew had lifted the whole group onto the helicopter and headed back to River City.

Later, the group reconvened at the Library. Professor Hazelton thanked the NeuroExplorers for their quick thinking. Then, with unmitigated enthusiasm, she declared, "I fully intend to document our findings from the caves and tell everyone about the treasures preserved up in those canyon walls. We're going to get legal protection for the whole canyon so that this time, we can save those relics forever. Most important of all, I'm going to include all you NeuroExplorers, my newest and most energetic research collaborators, in my future excavation efforts!"

Notes

BrainLink℠ Adventures
Baylor College of Medicine
Houston, Texas
ISBN 1-888997-47-8

THE READING LINK

Reading activities to use with

Legacy of Lost Canyon

The NeuroExplorers in

A Curious Cave Conundrum

BrainLink® : Brain Chemistry

The Reading Links have been created as ready-to-use reading and writing activities that are directly related to BrainLink adventure stories. They are not intended to represent a comprehensive reading program. The activities are related to reading objectives common to many curricula and cover a range of grade and ability levels. Teachers may wish to select from these activities those that are most appropriate for their own students.

Prepared by
Baylor College of Medicine
Houston, Texas
2000

Word Meanings

Below are words from *Legacy of Lost Canyon* that can have multiple meanings. Look at the different meanings for each word in the boxes below, and then decide which meaning works best in the sentences that follow. Write the number of the correct meaning next to each sentence.

bound
1. determined; resolved
2. a limiting line; boundary
3. to move by leaping; bounce
4. fastened by or as if by a band; confined

_____ Josh was bound to arrive at the NeuroExplorers' meeting on time.
_____ Dr. Hazelton bound her skis to the car's rack before driving away.
_____ Kyle caught the football out of bounds.
_____ B.J. would bound down the hallway whenever she got a good grade.

dig
1. to break up, turn, or loosen with an implement
2. a cutting remark
3. to like; admire
4. an archeological excavation site, or the excavation itself

_____ Dr. Hazelton said, "I dig your hat, B.J."
_____ Max went outside to dig in the garden.
_____ Isley I's verbal dig hurt Isley II's feelings.
_____ The Brain said, "Tutankhamen's burial site in Egypt is, perhaps, the most important dig in history.

Below are the definitions of words used in *Legacy of Lost Canyon*. Write a sentence using each word. Your sentences should tell something about the story.

1. **indigenous** - having originated in and being produced, growing, living, or occurring naturally in a particular region or environment; innate, inborn
2. **cacophony** - harshness in the sound of words or phrases; dissonance
3. **pictograph** - an ancient or prehistoric drawing or painting on a rock wall
4. **navigate** - to make one's way over or through; traverse
5. **precipice** - a very steep or overhanging place
6. **conundrum** - a question or problem having only a conjectural answer; an intricate and difficult problem
7. **spelunker** - one who makes a hobby of exploring and studying caves

1. _____

_____

2. _____

_____

3. _____

_____

4. _____

_____

5. _____

_____

6. _____

_____

7. _____

_____

Details/Supporting Ideas

Describe, in as much detail as you can remember, the canyon trek that took Dr. Hazelton and the NeuroExplorers to the caves.

Do you remember the shaman's cave that Isley I and Lakeisha found accidentally by falling into it? From your memory, describe what Dr. Hazelton and the NeuroExplorers saw there.

Imagine that you have been asked to speak to a group of younger students about the dangers of drug abuse. Based on what you learned while reading *Legacy of Lost Canyon*, write out your speech below, explaining some of the ways that different drugs can affect the brain and nervous system.

Sequence of Events

Which of the events below happened **last** in the story? Write "4" next to it. Then number the other events (1–3) to show the order in which they occurred.

_____ Kyle almost slips off the canyon path.
_____ Jeb Hunnicutt finds himself all tied up.
_____ The NeuroExplorers meet Ms. Ching.
_____ Professor Hazelton explains the shaman's ritual to the NeuroExplorers.

Main Idea

Read the Science Box on page 10. Fill in the circle next to the sentence below that best expresses the main idea of that paragraph.

- O Hormones are chemicals that circulate in the bloodstream.
- O In times of danger, hormones can shut down a number of non-essential bodily functions, like digestion.
- O Hormones act as messengers to various parts of the body and can have a variety of effects on many parts at once.
- O Epinephrine is another name for the hormone adrenaline.

Read the Science Box on page 18. Fill in the circle next to the sentence below that best expresses the main idea of that paragraph.

- O Despite the highly addictive nature of nicotine, the greatest health risk of tobacco comes from the other chemicals it contains, which are linked to several types of cancers.
- O Abuse of mind-altering drugs can lead to permanent changes in the brain and other parts of the body.
- O Marijuana can damage memory regions of the brain and affect coordination and the senses.
- O Heroin changes the way nerve cells in the brain receive and process messages.

Read the chapter called "Overload" (pages 5–7). Fill in the circle next to the sentence below that best expresses the main idea of that chapter.

- O Dr. Hazelton had made several important discoveries at the ancient site, but had to stop the excavation before she and her team were able to study it thoroughly.
- O A midden is a garbage dump, where people living in caves would have placed their refuse.
- O Dr. Hazelton grew up in the Rocky River area and always was interested in the various artifacts she found there.
- O The Native American Heritage Society gives money to scientists who wish to study ancient civilizations.

Summary of a Selection

Write a short summary of the chapter called "Walking in Footsteps" (pages 3–5).

Read the chapters called "Hallucinogens" and "Vision Quest" (pages 16–21). Then, use as much detail as possible to describe what pictographs are, who made them, how pictographs were made, and what they might mean.

Cause and Effect

Why did Mr. Lopez caution the NeuroExplorers and suggest they get more information before going off to explore the old Native American excavation site? What were the effects of this suggestion?

What caused Dr. Hazelton to be so upset after she investigated the first cave?

What are three effects of Jeb Hunnicutt's theft of the pictographs?

What is the cause of Isley I's fall down into the hidden cave? What are the effects?

Point of View/Fact-Opinion

Facts are true. Opinions sometimes are stated as facts, but they might not be true. Decide whether each of the following statements related to the story is a fact or an opinion. Write **F** (Fact) or **O** (Opinion) in each space.

_____ There are pictographs in Tanzania. (pg. 1)

_____ The state water commission doesn't care about the indigenous people who lived near Rocky River. (pg. 3)

_____ Dr. Hazelton studied archeology in college. (pg. 6)

_____ Isley I has a pea-brain. (pg. 6)

_____ Neurons receive messages on branches called dendrites. (pg. 8)

_____ Much rock art was inspired by religious beliefs. (pg. 17)

_____ LSD contributes to chronic mental disorders. (pg. 18)

_____ A shaman entered another world while on his vision quest. (pg. 20)

_____ Jeb Hunnicutt was the person removing the pictographs from the caves. (pg. 22)

Inference/Generalization/Drawing Conclusions

Which of the following generalizations or conclusions can be made from the information given in the story, *Legacy of Lost Canyon*? Fill in the circle next to each correct statement.

- O It is safe to climb up the side of a canyon wall.
- O Libraries are great sources of hard-to-find information.
- O All caves have pictographs.
- O Remains from lost civilizations are very valuable.
- O Someone who abuses drugs can permanently damage his brain and nervous system.
- O Scientists are boring "brainiacs" and can't relate to students very well.
- O With proper training, equipment and supervision, spelunking can be exciting.
- O Native Americans had a complex and developed culture.

What does Dr. Hazelton think of Jeb Hunnicutt? Does she understand his motivation for stealing the pictographs? Would she really leave him tied up in the cave? Is it important to protect ancient artifacts, like the pictographs? Tell what you think, and explain why.

Predicting Future Outcomes

Think about what might happen after the end of this story. For instance, what becomes of Jeb Hunnicutt? Does he ever change his ways? Does he make up with Dr. Hazelton, or do they remain enemies? Is it possible that he might use his knowledge of the caves to help preserve them, rather than destroy them?

OR

Tell what might happen next for the NeuroExplorers. Do they return to the caves and assist Dr. Hazelton with her work? If so, what exciting discoveries do they find? What more do they learn about the indigenous people who lived in the caves? Describe the NeuroExplorers' adventures as junior spelunkers and archeologists.

Painting Pictures with Words

Sometimes words are used in an unusual way to "paint" a verbal picture and help us "see" what is being described. For example, someone might say, "He's as graceful as a three-legged rhinoceros." This form of speech, using "like" or "as" to compare two unlike things, is called a simile (SIHM-uh-lee). Similes can help us to understand the writer's meaning more clearly.

Look at these "word picture" sentences from *Legacy of Lost Canyon*. Then try to write three sentences of your own, using similes. You might describe a cave scene, or a canyon above a rushing river, the actions or feelings of one of the characters in the story, or whatever you like.

Sentences from *Legacy of Lost Canyon*

They felt like *they had landed in a different world.* (pg. 7)

"Did it occur to anyone else that we're just like *a string of neurons*, working together here?" Josh asked as he followed Kyle . (pg. 8)

It looked *as big as a billboard!* (pg. 16)

My Word Picture Sentence

1. _____

_____

2. _____

_____

3. _____

_____

My Picture

Now draw one of the "pictures" you have just "painted" with words.

SE

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ACTIVITIES

GUIDE FOR TEACHERS

Brain Chemistry

Field Test Edition

Nancy Moreno, Ph.D.
Barbara Tharp, M.S.

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Printed in the United States of America

15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

ISBN: 1-888997-46-X

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The activities described in this book are intended for school-age children under direct supervision of adults. The authors, Baylor College of Medicine and the publisher cannot be responsible for any accidents or injuries that may result from conduct of the activities, from not specifically following directions, or from ignoring cautions contained in the text.

Development of this BrainLink® unit was supported, in part, by funds from the National Institutes of Health, Science Education Partnership Award Program grant number R25 RR13454. The opinions, findings and conclusions expressed in this publication are solely those of the authors and do not necessarily reflect the views of Baylor College of Medicine, the sponsoring agency, or the publisher.

Design and production: Martha S. Young

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Science and Health for Kids!

These BrainLink Activities are designed to be used with other components of the Brain Chemistry unit:

BrainLink Adventures
Legacy of Lost Canyon

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Acknowledgments

The BrainLink project at Baylor College of Medicine has benefited from the vision and expertise of scientists and educators from a wide range of specialties. Our heartfelt appreciation goes to James Patrick, Ph.D., Professor and Head of the Division of Neuroscience, Stanley Appel, M.D., Professor and Chairman of Neurology, and Carlos Vallbona, M.D., Distinguished Service Professor and Chairman of Community Medicine at Baylor College of Medicine, who have lent their support and expertise to the project. We also express our gratitude to Marsha Matyas, Ph.D., and Katie Frampton of the American Physiological Society, who directed BrainLink field tests in the Washington, D.C. area.

Special thanks go to the National Institutes of Health, National Center for Research Resources, Science Education Partnership Award Program and to Sidney A. McNairy, Jr., Ph.D., D.Sc., for their support of the BrainLink project.

"The brain is the last and grandest biological frontier, the most complex thing we have yet discovered in our universe. It contains hundreds of billions of cells interlinked through trillions of connections. The brain boggles the mind."

James D. Watson
from *Discovering the Brain*
National Academy Press
1992

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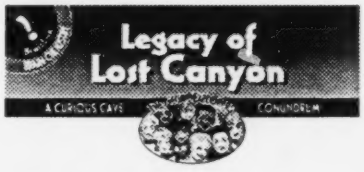
About BrainLink

The BrainLink Project's exciting *Activities*, *Explorations* and *Adventures* "link" students, teachers and parents to advanced knowledge of the brain and nervous system and to vital science and health information. Prepared by teams of educators, scientists and health specialists, each BrainLink unit focuses on a different aspect of the brain and the nervous system. The activity-based, discovery-oriented approach of the BrainLink materials is aligned with the *National Science Education Standards* and the *National Health Education Standards*.

The three components of each BrainLink unit help students learn why their brains make them special.

- *BrainLink Adventures* presents the escapades of the NeuroExplorers Club in an illustrated storybook that also teaches science and health concepts.



- *BrainLink Explorations for Children and Adults* is a colorful mini-magazine full of information, activities and fun things to do in class or at home.

- *BrainLink Activities - Guide for Teachers* presents activity-based lessons that entice students to discover concepts in science, mathematics and health through hands-on activities.

BrainLink materials offer flexibility and versatility and are adaptable to a variety of teaching and learning styles.

Where Do I Begin?

The *Adventures, Explorations* and *Activities* components of each BrainLink unit are designed to be used together to introduce and reinforce important concepts for students. To begin a BrainLink unit, some teachers prefer to generate students' interest by reading part or all of the *Adventures* story. Others use the cover of the *Explorations* mini-magazine as a way to create student enthusiasm and introduce the unit. Still others begin with the first discovery lesson in the *BrainLink Activities - Guide for Teachers.*

If this is your first BrainLink unit, you may want to use the pacing chart on the following page as a guide to integrating the three components of the unit into your schedule. When teaching BrainLink for 45 to 60 minutes daily, most teachers will complete an entire BrainLink unit with their students two to three weeks. If you use BrainLink every other day or once per week, one unit will take from three to nine weeks to teach, depending on the amount of time you spend on each session.

The *BrainLink Activities - Guide for Teachers* provides background information for you, the teacher, at the beginning of each activity. In addition, a listing of all materials, estimates of time needed to conduct activities and links to other components of the unit are given as aids for planning. Questioning strategies, follow-up activities and appropriate treatments for student-generated data also are provided. The final activity in each *BrainLink Activities - Guide for Teachers* is appropriate for assessing student mastery of concepts.

Using Cooperative Groups in the Classroom

Cooperative learning is a systematic way for students to work together in groups of two to four. It provides an organized setting for group interaction and enables students to share ideas and to learn from one another. Through such interactions, students are more likely to take responsibility for their own learning. The use of cooperative groups provides necessary support for reluctant learners, models community settings where cooperation is necessary, and enables the teacher to conduct hands-on investigations with fewer materials.

Organization is essential for cooperative learning to occur in a hands-on science classroom. There are materials to be managed, processes to be performed, results to be recorded and clean-up procedures to be followed. When students are "doing" science, each student must have a specific role, or chaos may follow.

The Teaming Up model* provides an efficient system. Four "jobs" are delineated: Principal Investigator, Materials Manager, Reporter, and Maintenance Director. Each job entails specific responsibilities. Students wear job badges that describe their duties. Tasks are rotated within each group for different activities, so that each student has an opportunity to experience all roles. Teachers even may want to make class charts to coordinate job assignments within groups.

Once a cooperative model for learning has been established in the classroom, students are able to conduct science activities in an organized and effective manner. All students are aware of their responsibilities and are able to contribute to successful group efforts.

* Jones, R. M. 1990. Teaming Up! LaPorte, Texas: ITGROUP.

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Materials

You will need the following materials to teach this unit.

Activity 1. **Know Your Brain**
You will need:
- zip top bag filled with cooked oatmeal, soft butter or pudding
- human brain model (optional)

Each group of students will need:
- brain balloon filled with water
- copies of "Your Brain" and "Mammal Brains" sheets
- colored markers

Activity 2. **Looking at Neurons**
You will need:
- overhead transparency of "Neurons and Synapses" page
- human brain model (optional)

Each student will need:
- copy of "Neurons and Synapses" page
- play dough, modeling clay or round styrofoam ball
- several pipe cleaners
- masking tape

Activity 3. **Neuron Communication**
Each group of students will need:
- 9-volt battery
- bulb with wire on either side (from holiday light set; see Set-up)
- 2 pieces of insulated copper wire (from holiday light set; see Set-up)
- 2 plastic portion cups or plastic cups with 3/4 of the top cut off
- teaspoon of salt
- coffee stirrer
- 200 mL distilled water
- copy of "Neurons and Communication" page

Activity 4. **Messages Across the Gap**
Each group of students will need:
- one or two die (if two, should be of different colors)
- copies of "Neuron Firing Game" sheets (one per student)
- set of "Brain Chemical Cards" (one card per student)

Activity 5. **Fight or Flight**
Each student will need:
- copy of "Fight or Flight?" student sheet

Activity 6. **Calculating Risk**
Each student will need:
- scissors
- clear tape
- paper
- copies of "Risk in People's LIves" and "The Risks are Real" student sheets

Activity 7. **Brain Food**
Each student will need:
- copies of "Brain Food" and "Calculating Calcium" student pages
- notebook paper or science journal to create lists and charts

Each group of students will need:
- several "Nutrition Facts" labels cut from food packages

Activity 8. **Brain Choices**
Each student will need:
- notebook paper

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Know Your Brain

ACTIVITY 1

Background

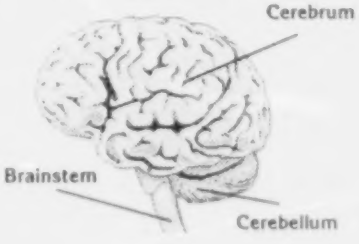
Did you ever wonder why you can respond so quickly when you are startled? Why you can "see" a picture in your mind's eye? Why you can remember facts, events and skills that you learned or experienced a long time ago? Your brain and nervous system make these and many more things possible.

Known as the command center of the body, the amazing brain is responsible for emotions, thoughts, movement and coordination of automatic body functions such as breathing. The brain's main communication channel to the rest of the body is the spinal cord, from which branch nerves to the rest of the body.

The brain—the most complex organ in the body—has three major parts, each with specific functions.

- The brainstem controls automatic functions of the body, such as heartbeat, digestion, breathing, swallowing, coughing and sneezing. It is connected to the spinal cord.
- The cerebellum sits at the back of the brainstem. It helps muscles work together for coordination and learning of rote movements. It controls the body's balance and also is involved in thinking tasks that are developed through repetition (learning the multiplication tables, for example).
- The cerebrum, the largest part of the mammalian brain, enables one to think, learn, remember, feel sensations and emotions, and move muscles purposefully.

The surface of the cerebrum has wrinkles, called gyri, which enable more tissue responsible for thinking to fit into a limited space. More wrinkles on the cerebral surface are believed to correlate with higher intelligence levels among various animal species. However, within a species, all individuals have similar patterns of folds.



The general structure of the brains of all mammals is similar. Each has three major regions—the cerebellum, the cerebrum and the brainstem. As the needs and behaviors of different animal species have changed over long periods of time, so have their brains. The greatest variation can be seen in the cerebrum, which is larger (relative to body size) and more wrinkled in humans than in any other animal.

Links

This activity may be taught along with the following components of the Brain Chemistry unit.

CONCEPTS

- The brain is the command center of the body.
- The brain has unique physical characteristics.
- The brain is specialized into many different areas, each with a different job.

OVERVIEW

This pre-assessment/awareness activity introduces students to the brain, the most complex organ of the body, and some of its most important functions.

SCIENCE & MATH SKILLS

Observing, measuring, predicting

TIME

Preparation: 10 minutes
Class: 30–45 minutes

MATERIALS

You will need:

- zip top bag filled with cooked oatmeal, soft butter or pudding
- human brain model (optional)

Each group of students will need:

- brain balloon filled with water
- copies of "Your Brain" and "Mammal Brains" sheets
- colored markers

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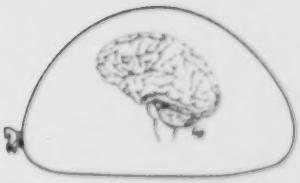
***Legacy of Lost Canyon* chapter:**
Overload (also see science box page 6)

Note. If this is your students' first BrainLink Adventure, have them read the introductory sections of the book—The Beginning and The Club Members—before continuing with the chapter listed above.

Set-up

The first part of this activity is teacher-directed and is best presented as whole class instruction. The second part should be completed by students working in groups of 2–4 individuals.

Prior to class, fill a "brain" balloon with water for each group of students. To do this, first stretch the balloon. Then fill it with water by placing the open end of the balloon over a faucet until it contains approximately three pounds (48 ounces or 1450 mL) of water. Use a scale or compare the balloon to something of appropriate weight to estimate when you have reached three pounds.

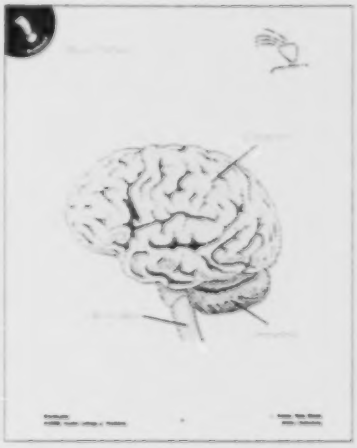


Brain balloon filled with water

Individual talents and skills cannot be predicted based upon the appearance of someone's brain. All humans have brains of about the same size with the same pattern of wrinkling. Differences among individuals are determined by the numbers and kinds of connections among nerve cells within each person's brain.

Procedure

1. Initiate a class discussion by asking student to share what they already know about the brain. On the board, make a list of things students think they know about the brain and of things they would like to find out. To help them along, ask questions such as, *Where is the brain located?* (inside head). *How much would you predict the average brain weighs?* (three pounds). *Is the brain the same all the way through or does it have different areas?* (brain has specialized areas—many of which are only partially understood).
2. Explain to students that even though scientists have learned much about the brain, there still are many unanswered questions. This lesson will help them learn about the basic organization of the brain.
3. Show a brain balloon to the class. Use the information listed in the "Brain Facts" box to expand on students comments. You might say something like:
   - *Did you know the average brain weigh about 1.45 kg (three pounds)? That is about the same as this balloon filled with water. Pass the balloon around so students can feel its weight.*
   - *Did you know that the brain is about the consistency of cooked oatmeal or butter at room temperature? Pass around a zip top bag filled with one of these substances for students to feel.* Follow by asking, *Based on what you have seen, is the brain sturdier or more fragile than what you expected?*
4. Give a water-filled "brain balloon" and copies of the "Your Brain" sheet to each group of students and reiterate that the brain balloon is about the same size and weight as a human



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brain. Introduce the three main parts of the brain and have students locate each on their balloons and sheets. You may want to have students color or label each of the three parts on their drawings.

Make sure that students note that the brainstem is located at the back of the brain and is connected to the spinal cord. Slightly above the brainstem is the cerebellum, which is about the size of a tennis ball. The cerebrum, the largest section of the brain, has many wrinkles. If you look at the brain from the top, there are two distinct halves or hemispheres.

5. Explain that the wrinkles drawn on the brain balloon and "Your Brain" page represent folds in the brain's surface. These folds—called gyri—enable needed brain material to fit into a limited space. If you have a human brain model available, show the parts to the students. Point out that all humans have about the same pattern of folds in their brains.

6. Ask, *How do you think the human brain compares to the brains of other mammals?* Challenge students to think about and draw what they think the brain of a rabbit, a cat and a chimpanzee might look like. Students should keep in mind that the brains of each of these kinds of animals have the same three parts—brainstem, cerebellum and cerebrum—as a human brain. At the same time, they should discuss the types of activities that each of these animals undertakes and whether these activities reflect how smart the animal is (For example, *Does the animal live in a social group? Hunt by stalking? Use complex foraging strategies, etc.?*)

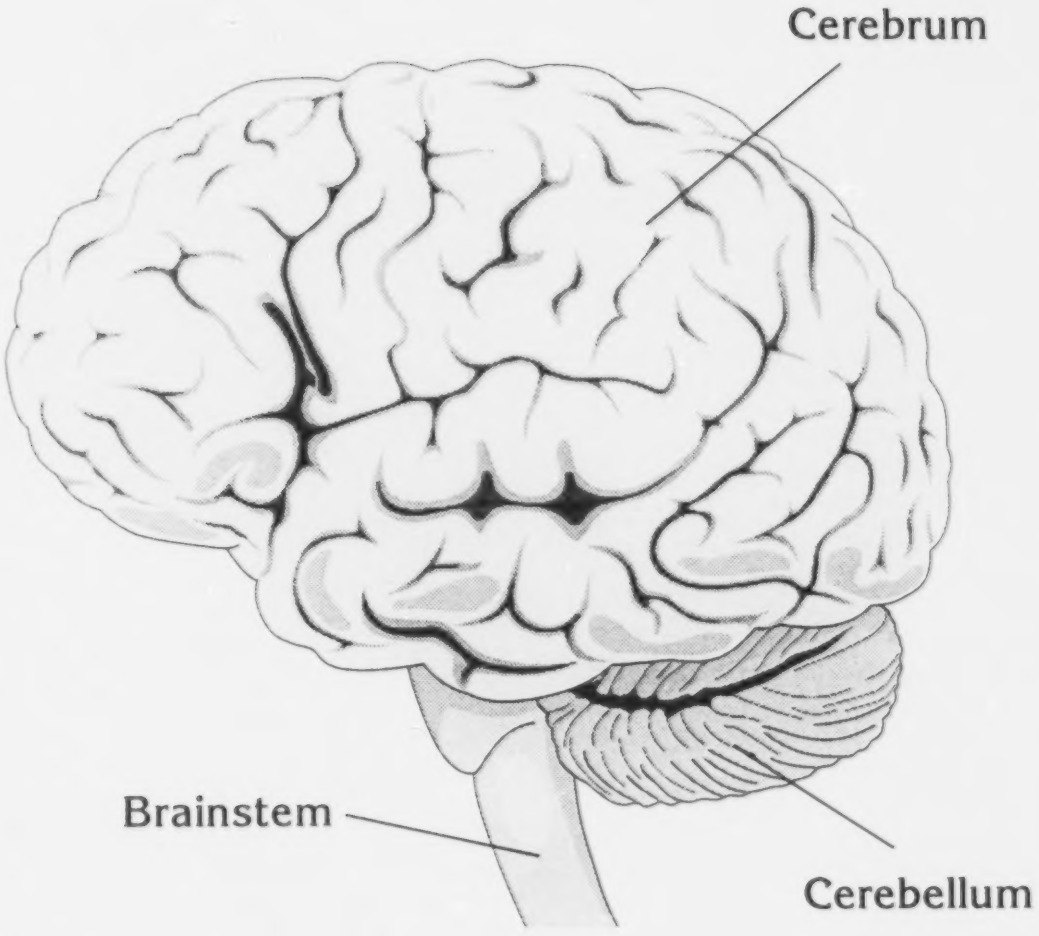
7. Distribute the "Mammal Brains" sheets to each group of students and have students compare their predictions to the brains depicted. Ask, *Are you surprised by the appearance of the animal brains? What makes the human brain special?* Point out that the opossum and rabbit brains have small cerebrums, without wrinkles. Help student notice that the relative size and amount of gyri in the cerebrums increase as they move toward the larger and more complex human brain. Students also should note that the brainstem and cerebellums remain relatively unchanged in all of the examples.

8. Conclude by referring to the students' list created at the beginning of the class period. Have students provide answers to as many of the questions that they asked as possible, and add new information to their list of things they know about the brain. Mention that they will be learning more about the brain over the next several classes and that many more of the questions that they posed will be answered. You also may ask for volunteers to look for the answers to specific questions using the library or Internet.

BRAIN FACTS

- An average brain weighs about three pounds.
- Brain tissue is about 80% water.
- The brain contains over 100 billion neurons (equivalent to the number of stars in the milky way).
- The brain is contained within and protected by the skull.
- The brain is divided into left and right halves.
- The brain has three main parts, each with a special job (cerebrum, where thinking and processing of sensory information takes place; cerebellum, which coordinates well-learned muscle movements; and brainstem, which governs automatics functions such as breathing and heart beat).
- The texture of the brain is like warm butter, cooked oatmeal or pudding.
- The brain is pinkish-gray in color.
- The human cerebrum is very wrinkled — the folds allow more cells responsible for thinking to crowd within the skull.

Your Brain



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Mammal Brains

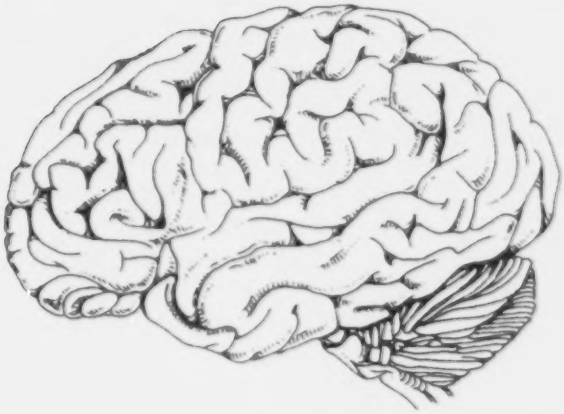
Opossum

Rabbit

Cat

Monkey

Chimpanzee



Man

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Looking at Neurons

ACTIVITY 2

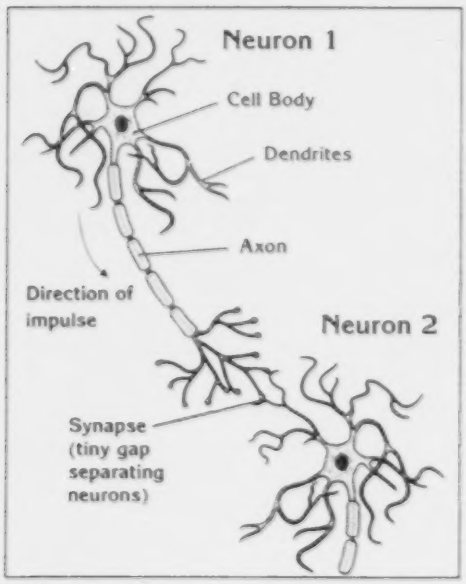
Background

The human brain is the most complex structure that we know about. Consisting of close to 100 billion cells, the brain is the center of our thoughts and emotions. It receives and processes information from the world around us, directs our movements and controls automatic functions of our bodies. Amazingly, all of the functions of the brain and nervous system are based on communication among nerve cells or neurons.

The brain and spinal cord make up the central nervous system. All of the other nerves in the body form the peripheral nervous system.

In many ways, a neuron is like any other cell in the body. Each neuron is surrounded by a membrane, is filled with liquid and has a nucleus containing its genetic material. However, just as many other cells within the body are specialized to do a particular job, neurons are specialized to receive and transmit information. Even though neurons may differ in appearance, all neurons are organized to collect information either from the environment (information detected by the senses) or from other cells. They transmit the information to neurons and other kinds of cells (such as muscle).

A typical neuron has an enlarged area, the cell body, which contains the nucleus, and several branches, or nerve fibers. The branches on which information is received are known as dendrites. Each neuron usually has many dendrites. Each neuron usually also has a longer tail-like branch or axon, which transmits information to other cells. A single neuron may be capable of receiving messages from several thousand different cells on its dendrites and cell body.



The axon of one neuron usually is separated from the next cell by a tiny gap called a synapse. Messages traveling from one neuron to the next must cross this gap in order for the signal to continue along its path.

CONCEPTS

- Messages within the brain and nervous system are sent very rapidly.
- Messages are conducted by living cells—neurons.
- Neurons are specialized to receive and transmit messages.

OVERVIEW

Students are introduced to how messages are sent and received by neurons, and build a model neuron.

SCIENCE & MATH SKILLS

Predicting, inferring, modeling

TIME

Preparation: 10 minutes
Class: 30–45 minutes

MATERIALS

You will need:

- overhead transparency of "Neurons and Synapses" page
- human brain model (optional)

Each student will need:

- copy of "Neurons and Synapses" page
- play dough, modeling clay or round styrofoam ball
- several pipe cleaners
- masking tape

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This activity provides students with a general introduction to neurons and to their role as message carriers within the body.

Links

This activity may be taught along with the following components of the Brain Chemistry unit.

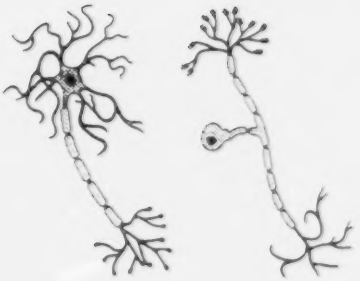
Legacy of Lost Canyon chapter:
The Trail (also see science box page 8)

Set-up

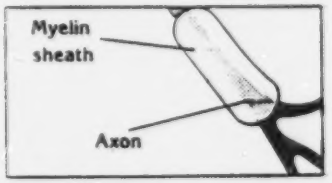
Conduct the initial portion of this activity with the entire class. Then divide the class into groups of four students to build their neuron models.

Procedure

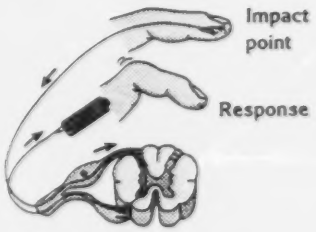
1. Begin by asking students about what happens when someone touches something hot. Ask, *When you accidentally touch a hot dish or iron, what happens?* Students might mention that they jerk their hands away quickly from the hot item. Ask, *Does your reaction happen slowly or rapidly? Why might that be important?*
2. Briefly outline the basic steps in a simple reflex reaction such as the one described above. *Receptors in the skin detect the presence of something hot. These receptors send a message to the spinal cord. In the spinal cord, a signal is sent immediately to muscles in the arm telling them to move. Another signal is sent up to the brain, alerting it to the situation.* Point out to students that components of the nervous system are able to conduct signals very quickly. Reflexes responses (which can be essential for survival) are especially rapid, because the signal does not travel all the way to the brain for processing.
3. Next ask students as a group to respond to some simple arithmetic questions. Ask, *What is two times four? Three times three? Three times nine? Ten times ten?* Follow by asking, *Did it take a long time for your brain to figure out the answers? How about to send messages to your lips and tongue to form the words?* Reiterate that components of the brain and nervous system communicate very rapidly.
4. Distribute copies or show an overhead transparency of the "Neurons and Synapses" page. Mention that there are many different kinds of neurons (about 10,000!), but that all of them are designed to carry messages. Help students find the "message-receiving" parts (dendrites and cell bodies) and "message transporting" parts (axons) on the different neurons. Point out the myelin sheath that surrounds the axons of some neurons and helps them conduct signals more rapidly (not unlike the insulation on an electrical wire). Mention that neurons only conduct signals in one direction.



Neurons differ in the human body. On the left is a typical motor neuron. On the right is a sensory neuron.



Signals are conducted electrically along the length of neurons. Some axons are wrapped into a special fat-containing membrane called a myelin sheath. The myelin sheath acts as an insulating layer and helps the axons conduct signals more rapidly.



Pathway of nerve impulse from impact point to spinal column and response.

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5. Using a variety of materials, challenge students to create their own neurons. Use clay or dough to create cell bodies and use pipe cleaners, wire or yarn to create axons and dendrites.
6. Provide masking tape for students to create short myelin sheath segments on the axons of their nerve cells.
7. After students have made their neurons, ask them to identify on their models where incoming messages would be received from other neurons and where their models would be able to transmit message to other neurons. Make sure that students understand that messages flow in only one direction on each neuron.
8. Display the neurons on a board or table. Or encourage students to work together to create networks of interconnected nerve cells that they have constructed.

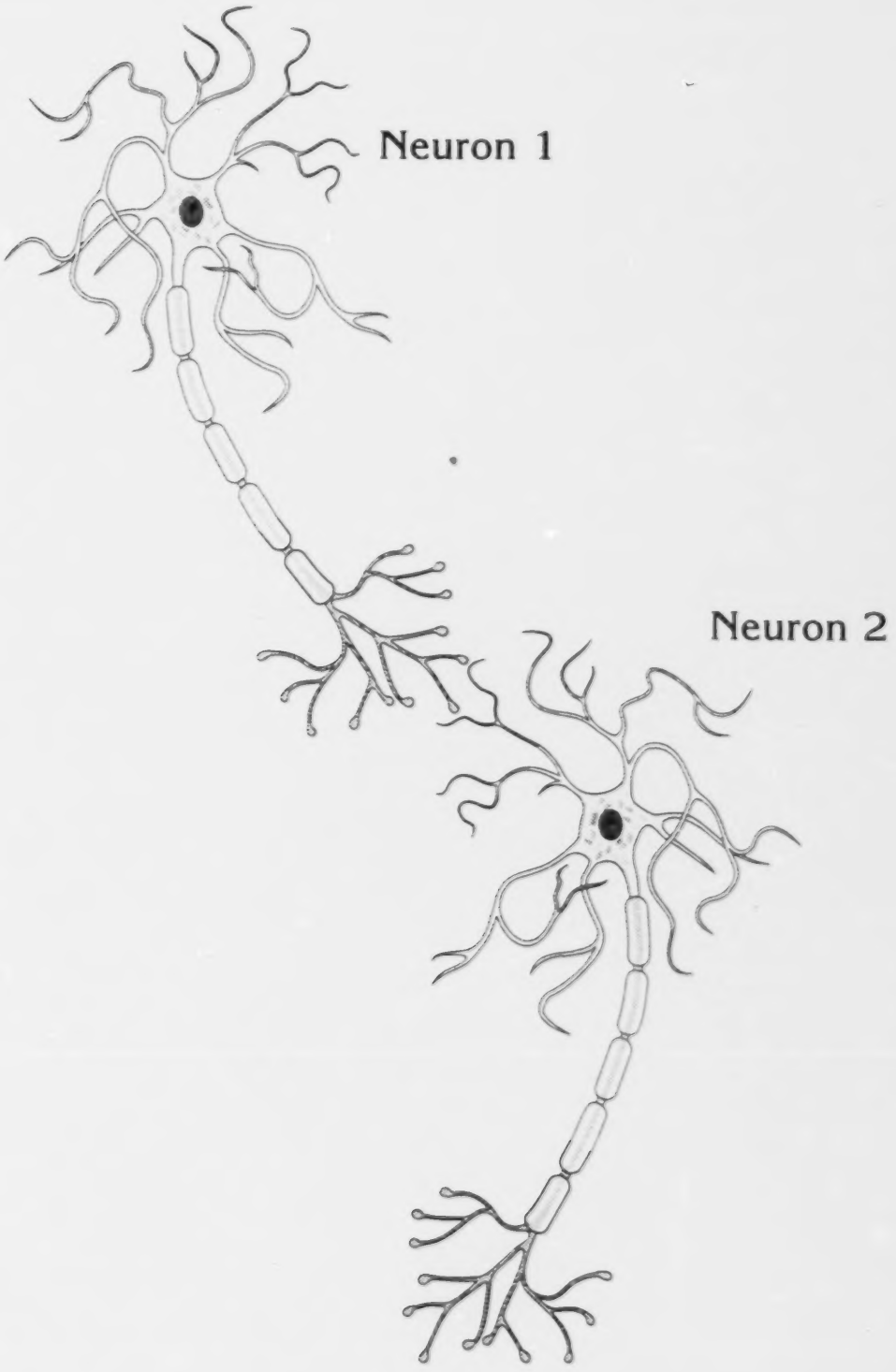
Typical student model

Brain Jogging

Here are more ideas for you and your students to explore.

- Try envisioning the following: If the cell body of a typical motor neuron (a neuron that sends messages to muscles) were the size a tennis ball, its dendrites would extend the length of a normal room and its axon would be about the size of a garden hose nearly 1/2-mile long.

Neurons and Synapses



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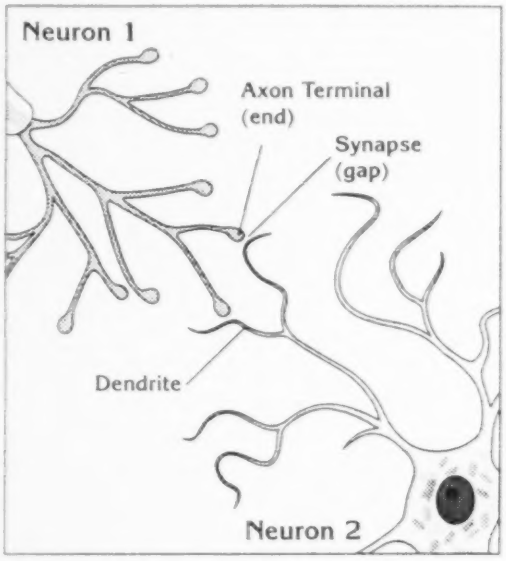
Neuron Communication

ACTIVITY 3

Background

Over a century ago, biologists discovered that nerve impulses somehow involved electricity. At first, they believed that electricity flowed through nerve cells much as it travels along a wire. However, they soon found that impulses moved along nerve cells much more slowly than electric current. They also discovered that only living nerve cells could conduct messages. Thus, something more than simple conduction of electricity was involved.



Eventually, biologists working on this question concluded that messages are transported along the cell membranes of neurons. Chemical changes along the length of the membrane cause the movement of an electrical charge from one end of the cell to the other. Thus, the movement of an impulse along a nerve cell resembles a line of dominoes, in which each domino triggers the next one to fall. Once the signal reaches the end of the axon, it is passed to the next nerve cell either electrically or by a chemical messenger that bridges the gap, or synapse, between nerve cells.

Both sodium, one of the components of salt, and potassium, are important for the movement of an electrical charge along the membrane of a nerve cell. This activity helps students observe the relationship among certain substances dissolved in water and the conduction of an electrical signal.

Links

This activity may be taught along with the following components of the Brain Chemistry unit.

Legacy of Lost Canyon chapter:
The Trail (also see science box page 10)

Set-up

You will need an inexpensive set of holiday lights for this activity. Cut the lights apart to create bulbs with wire extending from each

CONCEPTS

- Nervous system messages are sent as electrical signals along the length of living nerve cells (neurons).
- Messages must cross the gap between neurons (synapse).

OVERVIEW

Students create a simple electrical circuit and investigate the role of dissolved substances in conducting electricity.

SCIENCE & MATH SKILLS

Predicting, observing, recording observations, interpreting results

TIME

Preparation: 10 minutes
Class: 30–45 minutes

MATERIALS

Each group of students will need:

- 9-volt battery
- bulb with wire on either side (from holiday light set; see Set-up)
- 2 pieces of insulated copper wire (from holiday light set; see Set-up)
- 2 plastic portion cups or plastic cups with 3/4 of the top cut off
- teaspoon of salt
- coffee stirrer
- 200 mL distilled water
- copy of "Neurons and Communication" page

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side. Cut the rest of the wire into 12–24-in. pieces for students to use as the insulated wire in the activity.

In some geographic areas, tap water works as well as distilled water for this activity. Test tap water before class using the a battery and holiday light (same as student set-up).

Have groups of two to four students work together to carry out this activity.

Procedure

1. From a central location in the classroom, have a student from each group collect one 6-volt battery, one tree-light with connecting wire, two pieces of insulated copper wire (with ends stripped or provide wire-strippers for older students to prepare their own), two portion cups filled with about 5-mL of distilled water, a coffee stirrer and one teaspoon of salt in another portion cup.
2. Have students twist the end of one plain wire around one of the poles of the battery. Next, have them connect an end of the second piece of plain wire with one of the ends of the wire containing the bulb (by twisting them together). They should connect the other end of the plain wire to the remaining terminal on the battery. Let students test their connections by briefly touching the two free ends of wire together. If all connections are tight the bulb will burn brightly. If the bulb does not light, help students check all of the connections.
3. Ask, *Where is the source of energy for the bulb? Where is the electricity traveling?* Point out that electricity flows in only one direction (from the negative pole on the battery through the connecting wires to the positive pole). Make sure students understand that they have completed an electrical circuit. Relate this to nerve cells by pointing out that signals also travel along the length of neurons as very tiny electrical charges.
4. Ask each group to predict what will happen when they insert the two free wires into water. Mention that distilled water is completely pure and has no substances dissolved in it.
5. Let each group conduct the test and record their results. (The bulb will not light, because pure water does not conduct electricity.)
6. Now, direct each group to add the salt to the other container of water and swirl to dissolve as much salt as possible. Again, students should predict the outcome of inserting both free wires into the solution.
7. Have the groups conduct the test and record their results. (This time electricity will be conducted through the water, and the bulb will light.) For best results, have them submerge the wire connected to the negative terminal first. Next, they should submerge the other wire about 1–2 mm away from the first wire (i.e., close together, but not touching). Usually, the bulb

Nervous System

Student set-up

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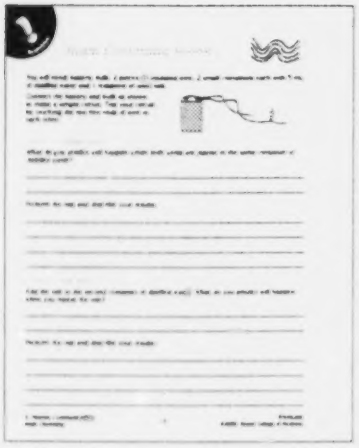
will glow for a fraction of a second. If students are having difficulty getting the bulb to light, have them swirl the cup of salt water before inserting the first wire.

Note. Students will observe bubbles forming at the end of the negatively charged wire. This is the result of a chemical reaction involving the copper wire and salt in the solution. The color of the water also will change to yellow.

8. Let the groups share their results. Ask, *What made the difference in whether the bulb would light?* (salt). Mention that salt, which breaks down into its components (sodium and chloride) in water, helped carry the electrical charge from one wire to the other and completed the electrical circuit. Lead students to understand that dissolved substances inside and outside the cell help signals travel along and between neurons. You also may want to point out that in some cases, the signal between neurons is conducted electrically.



Brain Jogging

Here are more ideas for you and your students to explore.

- Can you think of other examples that show the relationship between chemistry and electricity? Use the library or computing resources to investigate how batteries produce electrical current.

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Brain Communications

You will need: battery, bulb, 2 pieces of insulated wire, 2 small containers each with 5 mL of distilled water and 1 teaspoon of table salt.

Connect the battery and bulb as shown to make a simple circuit. Test your circuit by touching the two free ends of wire to each other.

TRIAL 1 - Distilled Water

What do you predict will happen when both wires are placed in the same container of distilled water?

Perform the test and describe your results.

TRIAL 2 - Salt Water

Add the salt to the second container of distilled water. What do you predict will happen when you repeat the test?

Perform the test and describe your results.

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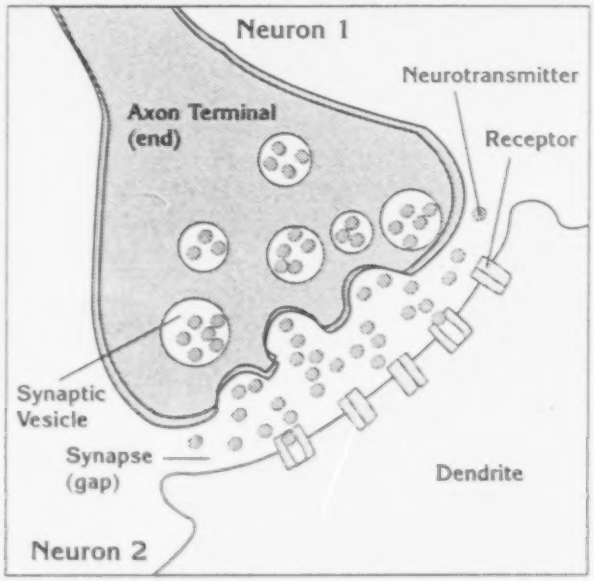
Messages Across the Gap

ACTIVITY 4

Background

Within each neuron, impulses are transmitted as an electrical charge that travels the length of the axon. However, when the signal reaches the end of the axon it must be passed to another neuron. A few kinds of nerves are coupled directly, so that an electrical signal traveling down one neuron passes unimpeded to the next one. This type of transmission from one neuron to another occurs very rapidly and is usually found in places in the nervous system where speed of conduction is important.



In most cases, however, communication across the synapse occurs chemically instead of electrically. The space between neurons usually is about 20 nanometers wide (one nanometer equals 0.000,000,1 centimeters). When a signal reaches the end (or terminal) of the axon of one neuron, it triggers the release of chemical messengers from special pockets. These chemical messengers, known as neurotransmitters, cross the synaptic gap and bind to special receptor molecules on the receiving neuron. The relationship between neurotransmitters and their receptors is very specific. The joining of the neurotransmitters to their specific receptors can cause a new impulse to be generated (or to "fire") along the membrane of the second neuron.

The story does not end, however, with the binding of chemical messengers to receptors on the next neuron. If the messengers remained in place, the next neuron would be stimulated indefinitely, so a mechanism to destroy the messenger also must exist. Usually, other chemicals within the neurons break the messengers into smaller molecules, which diffuse back into the synaptic gap.

Not all chemical messengers stimulate neurons to fire. Some messengers actually make it harder for neurons to fire. Thus, there can be two different effects of chemical messengers on neurons: an

CONCEPTS

- A neuron can receive messages from and transmit messages to many other cells.
- Messages can either stimulate the next neuron to also send a signal or inhibit that neuron from sending a signal.
- Certain chemicals change the way signals are sent and received.

OVERVIEW

Students play a simple game in groups to demonstrate how multiple incoming signals influence the action of neurons.

SCIENCE & MATH SKILLS

Recording observations, interpreting results

TIME

Preparation: 10 minutes
Class: 30–45 minutes

MATERIALS

Each group of students will need:

- one or two die (if two, should be of different colors)
- copies of "Neuron Firing Game" sheets (one per student)
- set of "Brain Chemical Cards" (one card per student)

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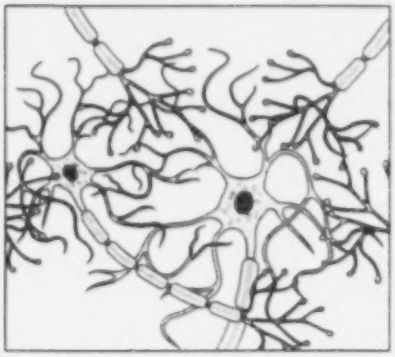

impulse can be triggered or the firing of the neuron can be inhibited. Since one neuron can share synapses with thousands of other neurons, the combined effects of different messages ultimately determines whether a nervous system signal will be triggered in the next neuron in a network.

The chemical messengers or neurotransmitters that cross the gap between neurons or between neurons and another kind of cell, such as a muscle, are designed to match up very specifically with a particular receptor. This match is based on the shapes of the messenger and the receptor. In other words, the messenger fits the receptor in a way similar to the way that a key fits a lock.

There are many kinds of receptors on neurons and other cells. Hormones in the body, for example, also act by binding to specific receptors on the outside of target cells. Hormone receptors are found in many neurons and in the cells of certain glands. In all cases, a chemical messenger (whether a neurotransmitter or a hormone) only can affect a cell that has the corresponding receptors.

Many drugs have powerful effects on the nervous system because they act on receptors on neurons. Some drugs trick the receptor by matching part of the shape of the chemical messenger that is supposed to attach to the receptor. Once attached, however, the drugs can produce very different results. Curare, for example, is a deadly poison used by South American Indians. It causes death from paralysis, because it binds to receptors on muscle cells, but doesn't stimulate the muscles to contract. Since it blocks the receptors, the real chemical messenger (acetylcholine) can no longer bind to the site, leading to paralysis.

Drugs also can interfere with communication between neurons by interfering with the manufacturing mechanism within cells to create chemical messengers, by blocking storage of the messengers or by preventing release of chemical messengers. Some drugs cause excessive firing of neurons by stimulating massive releases of neurotransmitters, by mimicking the effects of chemical messengers or by preventing the normal breakdown of chemical messengers once they have caused a target neuron to fire.

This activity will help students learn about the relationships between chemical messengers, receptors and the actions of common drugs.

Links

This activity may be taught along with the following components of the Brain Chemistry unit.

DRUGS & THE NERVOUS SYSTEM

Research has provided at least partial explanations of how some drugs affect the nervous system.

Nicotine, contained in cigarettes, acts as a stimulant because it mimics the effects of chemical messengers from neurons to muscles of the body.

Morphine (and heroin, which is converted into morphine by the body) mimics chemical messengers in the brain that trigger neuron pathways responsible for pleasure and blocking of pain.

Cocaine and amphetamines ("speed"), which act as stimulants, interfere with the uptake of a neurotransmitter that causes certain neurons in the brain to fire.

Alcohol, which causes slower movements, sleepiness and loss of alertness, interferes with the reception of a chemical messenger that prevents neurons from firing.

L-Dopa, an important drug for treating Parkinson's disease, provides raw material for an important chemical messenger to muscles.

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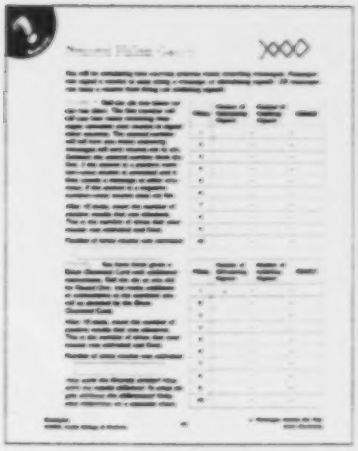
Legacy of Lost Canyon **chapter:**
Hallucinogens (also see science boxes on pages 17, 18 and 19)

Set-up

Have students work in groups of four to carry out this activity, which is played as a game

Procedure

1. Using the neuron models that students have created (Activity 2), review the basic parts of the neuron: dendrites (where signals are received), cell body (also receives signals) and axon (transmits signal). Next, remind students of the activity they recently completed. Ask, *How did the electricity get through the water between the two wires in the circuit you made?* Students should remember that salt dissolved in the water facilitated the movement of electricity (negatively charged chloride ions moved toward the wire connected to the positive pole of the battery).
2. Mention that neurons also are able to communicate across a water-filled gap between cells. Distribute copies or project a transparency of the "Neurons and Synapses" page (Activity 2). Have students identify the two neurons in the drawing, as well as the axons and dendrites. Point to one of the dendrites near the top of the page and ask, *If a signal was traveling along this neuron, where would it go?* Help students understand that the signal will travel the length of the neuron.
3. Point to the gap between the two neurons and ask, *What happens here?* Help students understand that instead of dissolved salt, special chemical messengers (neurotransmitters) cross the gap to the next neuron. The messengers can tell the next neuron to fire or they can keep it from firing. Remind students of the previous activity in which salt dissolved in water carried the electrical "message" from one wire to the next.
4. Tell students that they will be modeling what happens when messengers or neurotransmitters go from one neuron to the next. Point out that in the body, most neurons can receive messages from many other neurons. Some of these message "stimulate" or excite firing, other messages "inhibit" or prevent firing.
5. Have students work in groups of four to complete the neuron firing game. Give a "Neuron Firing Game" sheet to each student. Students will take turns rolling a die twice: the first time will determine how many incoming signals excite their neuron to fire and the second time will determine how many signals inhibit firing (or have students use two different-colored die and roll them together). If the number of excitory or stimulating signals is greater, the neuron will "fire" or pass the message. If the number of inhibitory signals is greater, the



Researchers define a substance as a neurotransmitter when it meets the following criteria.

1. The substance can be found inside the neuron that is believed to release the neurotransmitter.
2. The substance is released in response to an electrical signal in the cell membrane.
3. Specific receptors for the substance can be found on the receiving neuron.

neuron will not fire. The student should record on his or her card, whether their neuron fired during that turn. The student who has "transmitted" the most messages after 10 rounds wins.

6. Conduct a class discussion of the results of the game thus far. *Did it matter how many "stimulating" messages were present for firing, as long as there were more than the "stopping" or "inhibiting" messages?* Point out that the firing of a neuron is like turning on a light switch, either an impulse is created or it is not. Mention that many chemicals and medicines can affect the transmission of messages between nerve cells by mimicking or interfering with the action of neurotransmitters.
7. Tell students that they will be conducting another round of the game. This time, however, give each student an additional "Brain Chemical" card that will provide additional instructions for each player. Depending on the action of the chemical, students will add or subtract to the numbers that they roll for stimulation or inhibition of neuron firing. As they play the game, students will discover that the drugs have changed the patterns of neuron activation.
8. After students have completed the second round, ask, *Did you receive different results this time? Did your neuron fire more or less often? Did the response of your neuron change over time?* Help students to conclude that each of the chemicals on the "Brain Chemical" cards changes the way neurotransmitters work. In addition, in at least two of the examples (cocaine and inhalants), lasting changes in neurons occurred. Have revisit their neuron to find the places affected by these chemicals.
9. Encourage students to learn more about how different chemicals affect the brain by conducting research on the Internet. A good places to start is the National Institute on Drug Abuse at <www.nih.nida.gov>.

Disorders such as depression, anxiety and schizophrenia often are treated by medicines that affect one or more steps in the synthesis, release or breakdown of certain neurotransmitters. In fact, learning how these drugs work has provided insight into the mechanisms in the brain underlying these diseases.

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Neuron Firing Game

You will be simulating how neurons process many incoming messages. Messages can signal a neuron to pass along a message (a stimulating signal). OR messages can keep a neuron from firing (an inhibiting signal).

ROUND 1. Roll the die two times (or use two dice). The first number will tell you how many incoming messages stimulate your neuron to signal other neurons. The second number will tell how you many incoming messages tell your neuron not to act. Subtract the second number from the first. If the answer is a positive number—your neuron is activated and it fires (sends a message to other neurons). If the answer is a negative number—your neuron does not fire.

After 10 trials, count the number of positive results that you obtained. This is the number of times that your neuron was activated and fired.

Number of times neuron was activated

TRIAL	Number of Stimulating Signals		Number of Inhibiting Signals		RESULT
1		–		=	
2		–		=	
3		–		=	
4		–		=	
5		–		=	
6		–		=	
7		–		=	
8		–		=	
9		–		=	
10		–		=	

ROUND 2. You have been given a Brain Chemical Card with additional instructions. Roll the die as you did for Round One, but make additions or subtractions to the numbers you roll as directed by the Brain Chemical Card.

After 10 trials, count the number of positive results that you obtained. This is the number of times that your neuron was activated and fired.

Number of times neuron was activated

TRIAL	Number of Stimulating Signals		Number of Inhibiting Signals		RESULT
1		–		=	
2		–		=	
3		–		=	
4		–		=	
5		–		=	
6		–		=	
7		–		=	
8		–		=	
9		–		=	
10		–		=	

How were the Rounds similar? How were the results different? To what do you attribute the differences? Write your responses on a separate sheet.

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Brain Chemical Cards

ALCOHOL

Causes slower movements, sleepiness and loss of alertness, because it interferes with both kinds of nervous system signals.

All trials: Subtract two from both numbers you roll.

COCAINE

Causes a build-up of a neurotransmitter called dopamine in synapses and leads to a temporary increase in firing among neurons in the pleasure part of the brain. After a while, neurons adjust to these higher levels so that neurotransmitters are not as effective.

Trials 1 and 2: Add three to the first number (stimulating signals) you roll.

Trials 3 and 4: Add one to the first number.

Trials 5 and 6. Do not add or subtract any numbers.

Trials 7 and 8: Subtract one from the first number.

Trials 9 and 10: Subtract two from the first number.

INHALANTS

Prevent messages from traveling along neurons because they damage the myelin sheath on axons.

Trials 1, 2 and 3: Subtract one from both numbers you roll

Trials 4, 5 and 6: Subtract two from both numbers you roll.

For the rest of the trials: Subtract three from both numbers you roll.

NICOTINE

Acts as a stimulant because it mimics the effects of chemical messengers from neurons to muscles of the body.

Trials 1–5: Add two to the first number you roll.

Trials 6–10: Add one to the first number you roll.

BrainLink
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Fight or Flight

ACTIVITY 5

Background

Stress is a common condition within modern society. Most of us can recognize the symptoms: feelings of nervousness, sweating from the palms of the hands, pounding of the heart or a dry mouth. These sensations are signs that the body is preparing for a difficult situation, in which survival may be at stake. Remarkably, all of the reactions of our bodies to stress are controlled by the brain. Immediate stress reactions are directed through pathways in the brainstem and spinal cord to the major internal organs of the body. However, chemicals circulating in the bloodstream also help prepare the body to handle a crisis. The brain coordinates the release of these chemicals, which belong to the family of messengers known as hormones.

Unlike the chemical messengers between neurons (neurotransmitters), hormones can have wide-reaching effects on many different tissues in the body at the same time. Hormones, which circulate directly in the bloodstream, act as messengers to the nervous system and other tissues in the body. Hormones only are able to act on cells that have the right kind of receptors.

Hormones have many vital functions in mammals. Some of these include regulating digestion; controlling the metabolism of sugars, proteins and fats; and regulating growth and development. Many of our most basic drives—sleeping, hunger, thirst, sex—are regulated through hormones.

The master control system for all hormones in the body is located within the lower portion of the cerebrum. Known as the hypothalamus, this small structure interconnects with many regions of the brain. It is adjacent to the pituitary gland, which produces hormones that control other glands in the body. Together, the hypothalamus and the pituitary gland regulate a wide range of body functions. During periods of stress, these tiny structures direct two small glands near the kidneys to produce hormones, such as adrenaline (also called epinephrine), that prepare the body for action.

Links

This activity may be taught along with the following components of the Brain Chemistry unit.

Legacy of Lost Canyon chapter:
The Trail (also see science box page 10)

Set-up

Begin this activity as a discussion with the entire class. Have students work individually for the writing portion of the activity and in groups of four to share results and brainstorm stress-reducing solutions.

CONCEPTS

- The brain coordinates the release of chemicals called hormones, that affect many different tissues at the same time.
- The reaction to stressful situations is mediated by hormones.

OVERVIEW

Students will describe a stressful situation and how their bodies prepared for action.

SCIENCE & MATH SKILLS

Observing, sequencing, interpreting, observing

TIME

Preparation: 5 minutes
Class: 30–45 minutes

MATERIALS

Each group of students will need:

- copy of "Fight or Flight?" student sheet

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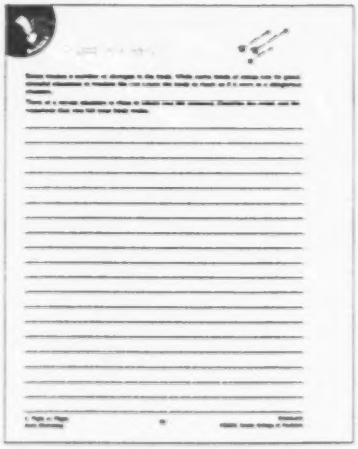
Procedure

Session 1.

1. Ask students, *Have you ever been in a situation where you felt nervous, felt your heart pounding and your hands became sweaty? Why do you think that you felt the way you did?* Encourage students to share a few experiences.
2. Next, ask, *Why do you think your body felt that way?* Help students understand that their bodies were responding to a possibly difficult situation. Ask, *How did your bodies know that the situation might be stressful?* Lead students to understand that their brains used information coming from the senses and information retrieved from memory to decide which actions needed to be taken.
3. Mention that stress is a reaction by many different parts of the body to help an organisms survive. Ask, *Can you think of any situations that might be stressful for an animal that is prey to other animals? How about other kinds of difficult situations for animals in their natural surroundings?* Help students understand that under stress many changes take place very rapidly in the body. These changes include an increase in blood pressure, an increase in fuel for the brain and a partial shut-down of body systems (such as the digestive system) not needed for fighting or running. Mention that all of these changes are directed by the brain, both directly through the brainstem and spinal cord, and indirectly, by controlling chemical messengers, such as the hormone adrenaline, that circulate in the blood to many parts of the body. Ask, *When do you think it might be important for humans to be able to respond quickly and efficiently?*
4. Mention that while these reactions can sometimes improve performance by the body, there are many situations in modern life in which the body's "fight or flight" reaction to stress can be unhealthy. Distribute a copy of the "Fight or Flight?" page to each student. Ask each student to think of a stressful situation that has happened in class and to describe it as indicated on the sheet.

During periods of stress, non-essential bodily functions, such as digestion, are shut down. In addition, the amount of glucose (an important fuel for the brain) and amino acids (necessary to repair damage to muscles) in the blood is increased. Blood pressure becomes elevated. All of these changes might help an animal deal with a life-threatening situation, but are not healthy on a long-term basis.



Session 2.

1. Before students begin working in small groups, ask, *Did any of you have a hard time thinking of a situation that was stressful at school? Do you think that there was anything that you could have done that might have made the scenario that you described less stressful?*
2. Direct students to share the experiences that they described with one another in their groups. Then, as a group, ask students to decide if there was anything that could have been done to make each situation less stressful. You might want to mention some general stress-reducing strategies, such as being prepared in advance for tests, home-work assignments, etc.;

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allowing adequate time to finish tasks; planning for situations in advance; learning to recognize potentially stressful social situations and finding an appropriate response; creating a mental picture of a successful outcome; and, even, breathing slowly and calmly. Mention that since the brain interprets and controls the stress reaction, there are certain things that can be done to reduce stress.

3. Have each group share some of the stress-reducing strategies that they discussed. Make a list on the board of the strategies. Ask, *Do you think that any of these strategies will work for situations outside of school?*

Tissues that produce and release hormones are known as endocrine tissues. The word, endocrine, comes from the Greek *endo* (meaning within) and *krinein* (meaning to secrete). Hormones are released directly into the blood.

Brain Jogging

Here are more ideas for you and your students to explore.

- Different species of animals react differently to dangerous situations. Some animals flee, others become motionless so that they blend into the background, some look for a safe place to hide, and still others wait for an opportunity to fight. Investigate the habits and lifestyles of various animals to find out how they react to life-threatening scenarios. How are the responses related to specific characteristics of the animals (fast runners, good fighters, etc.) and to the characteristics of the environments in which they live?

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Fight or Flight?

Stress causes a number of changes in the body. While some kinds of stress can be good, stressful situations in modern life can cause the body to react as if it were in a dangerous situation.

Think of a recent situation in class in which you felt stressed. Describe the event and the responses that you felt your body make.

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Calculating Risk

ACTIVITY 6

Background

People perceive risks differently, depending on the nature of the risk and their individual experiences. Risk perceptions are strongly influenced by issues of choice and control. Thus, risks often seem "riskier" to people if they have not voluntarily chosen to bear them. Conversely, people are more willing to accept or ignore risks if they make a choice voluntarily and/or if the immediate benefit seems to outweigh the potential for negative outcomes much later in time. In the case of chemical substances that affect the brain, the risks can be very high indeed.

People have chosen to consume foods and other chemical substances that make them feel good temporarily or that alter their moods since before recorded history. Anthropologists have uncovered ancient uses of mind-altering substances for medicinal and ritualistic uses in a number of cultures around the world. It is important to note that, with most brain-altering chemicals, the choice to begin use is voluntary. Over time, however, the brain and body adapt to the effects of the chemical creating a new "normal" state that is adjusted for the presence of the introduced substance. This leads to a physical dependence or "craving" for the substance that is no longer voluntary and also may lead to consumption of the substance in increasingly higher and more damaging amounts.

Today, for example, more than 80 percent of the US population chooses to consume the stimulant caffeine in coffee and/or cola drinks, because of its taste or its perceived enhancement of mental and physical performance. At the same time, most of these caffeine-consumers have developed a dependence on its stimulating effects and experience mild withdrawal symptoms, such as sleepiness and headaches, when they do not have caffeine. Other chemicals have more dramatic effects on the brain and body. Many of these affect the part of the brain responsible for generating feeling of pleasure or well-being. These feeling, however, usually decrease after the first few uses of the substance.

Drugs that act on pathways related to pleasure in the brain are sometimes used inappropriately by people because they would like to change the way they feel. Unfortunately, the continued use of some kinds of drugs can actually change the way the brain works. This is the biological basis of addiction.

Many mind-altering chemicals that are abused by children and adults in the US lead to permanent changes in the brain and other parts of the body. Marijuana use can damage memory regions of the brain, in addition to affecting coordination and the senses. Heroin changes the way nerve cells in the brain receive and process messages. Inhalants, which are taken up by fatty tissue in the body,

CONCEPTS

- Perception of risk is affected by personal choices.
- Many chemicals influence the function of the brain and nervous system.
- Risks to personal health can become high with use of tobacco, alcohol and many drugs.

OVERVIEW

Students will compare their estimations of risk to the real probabilities of a number of events.

SCIENCE & MATH SKILLS

Predicting, inferring, understanding probability

TIME

Preparation: 10 minutes
Class: 30–45 minutes

MATERIALS

Each student will need:

- scissors
- clear tape
- paper
- copies of "Risk in People's Lives" and "The Risks are Real" student sheets

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can damage the fat-containing myelin sheath on nerve cell axons. LSD has been found to contribute to the development of chronic mental disorders. Alcohol, which depresses physical and mental abilities, damages many tissues throughout the body, including the liver and the brain. Alcohol also is a major contributing factor to automobile accidents. Nicotine, a stimulant in tobacco, is a very addictive substance—however, the greatest health risk comes from other compounds in cigarette and cigar smoke that are linked to the development of lung and other cancers.

Links

This activity may be taught along with the following components of the Brain Chemistry unit.

Legacy of Lost Canyon chapter:
Hallucinogens

Set-up

Begin with a class discussion, followed by students working in groups of 3–4 persons to complete the activity.

Procedure

1. Begin with a class discussion of chemical messengers in the brain. Ask, *Do you think it is possible to change how neurons send messages within the brain? How about when people purposely take something that affects the sending of messages in the brain?* Give students time to think of some of the most common substances people take to change how they feel. Examples include alcohol, coffee and soft drinks with caffeine, cigarettes (nicotine), marijuana, inhalants ("sniffing" glue, paint or aerosols), etc.
2. Follow by asking, *Do you think people take into consideration possible health risks when they take a mind-altering substance? Why or why not?*
3. Tell students that one way to quantify risk is to state it as a probability that something will occur. For example, when students rolled a die in Activity Four, they had a one in six chance of rolling a "two" on any given toss. Mention that by studying how frequently events have happened in the past, scientists and statisticians have been able to calculate the risk of many different types of occurrences.
4. Give each group of students a copy of the "Risk in People's Lives" sheet and have them read all of the statements. Have students cut the statements into strips (so that they easily can be rearranged). Next, have them discuss within their groups how likely they believe each of the events is and have them place the strips in order of likelihood from least risk to most risk. (You may want to provide tape and a separate sheet on which students can arrange their strips).

There is a difference between drug abuse and drug addiction. Drug abuse is a voluntary activity—the user makes a choice about taking a drug. Drug addiction is a compulsion—the need to use a drug is overwhelming. Eventually the body becomes "used" to addictive drugs, causing severe withdrawal symptoms when the substance is removed. In the end, addicted people continue drug use to avoid the pain of withdrawal—rather than deriving any pleasure from the experience.

Drug addiction and abuse is one of the most serious problems of our modern society. There are more than 10 million alcoholics in the United States. About 5.5 million people in the United States are addicted to illegal drugs.

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5. Discuss students predictions briefly by asking which events they placed at the tops and bottoms of their list. Let each group share some of their predictions and the reasoning behind their choices.
6. Distribute a copy of "The Risks Are Real" sheet to each group and give them students time to compare their predictions to the actual risk calculations.
7. Conclude by discussing the actual risks as compared to students' predictions. Ask questions such as, *Which ranking surprised you the most? Which were you able to predict most accurately? Do you think you or any of your friends might be ignoring long-term risks, because choices are being made based on short term benefits?*

Studies on how chemical messengers work within the brain and nervous system hold promise for unraveling many basic questions about the actions of drugs and the causes of some diseases. Almost all drugs that influence the way the brain works do so by altering the transmission of chemical messages. This can have important medical applications for the treatment of severe pain or illnesses such as schizophrenia or depression. Some medicines used to treat depression, for example, act on chemical messengers that are involved in regulating sleep and body temperature. Morphine, a potent pain medication, mimics the effects of a natural chemical messenger involved in brain pathways for minimizing pain and producing a sense of well-being.

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Risk In People's Lives

Read the statements below and rank them according to how likely you think they are to happen. Begin your list with the event that you think is least likely.

Cut the statements into strips to make them easier to sort and rank.

---

a. Being born left-handed

---

b. Living to the age of 116 years

---

c. Being killed by space debris

---

d. Picking all 5 winning numbers in a lottery (total of 49 numbers)

---

e. Quitting smoking successfully without any help

---

f. Becoming addicted to caffeine

---

g. Being electrocuted

---

h. Becoming a professional basketball player if you play basketball in high school

---

i. Becoming addicted to nicotine, if you smoke cigarettes

---

j. Being involved in an alcohol-related car crash

---

k. Having poor driving skills after smoking one marijuana cigarette

---

l. Being killed by falling out of bed

---

m. Permanently damaging the myelin sheath on nerve cells in the brain by "sniffing" paint, glue or other similar inhalants

---

n. Dying from influenza

---

o. Being pressured by a friend to smoke or use alcohol

---

p. Having a fatal accident while playing sports

---

q. Becoming dependent on crack or cocaine, if injected

---

r. Dying of a smoking-related illness, if you start smoking as a teenager

---

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The Risks Are Real

These are the real odds of each of the events that you ranked. Compare the real odds to your rankings. *Were there any surprises?*

Item	Odds
c. Being killed by space debris	1 in 5 billion
b. Living to the age of 116 years	1 in 2 billion
l. Being killed by falling out of bed	1 in 2 million
d. Picking all 5 winning numbers in a lottery (total of 49 numbers)	1 in 1,953,393
g. Being electrocuted	1 in 350,000
p. Having a fatal accident while playing sports	1 in 25,000
h. Becoming a professional basketball player if you play basketball in high school	1 in 10,000
n. Dying from influenza	1 in 5,000
e. Quitting smoking successfully without any help	1 in 10
a. Being born left-handed	1 in 5
q. Becoming dependent on crack or cocaine, if injected	1 in 4
r. Dying of a smoking-related illness, if you start smoking as a teenager	1 in 3
j. Being involved in an alcohol-related car crash	1 in 3
o. Being pressured by a friend to smoke or use alcohol	1 in 3
m. Permanently damaging the myelin sheath on nerve cells in the brain by "sniffing" paint, glue or other similar inhalants	1 in 2
i. Becoming addicted to nicotine, if you smoke cigarettes	1 in 2
f. Becoming addicted to caffeine	1 in 1.25
k. Having poor driving skills after smoking one marijuana cigarette	1 in 1

Compiled from public domain statistics made available by the National Institutes of Health, Center for Substance Abuse Prevention, National Clearing House for Alcohol and Drug Information, American Cancer Society, CareerQuest and Dartmouth University.

Brain Food

ACTIVITY 7

Background

The brain and nervous system require many different kinds of raw materials to carry out activities within cells and to manufacture the chemical messengers that communicate between neurons. These raw materials must come from our food. Surprisingly, glucose, a simple sugar molecule, is the only source of energy for cells in the brain. The amount of glucose in the blood is regulated by the liver, which also is important for the processing of fats and proteins. Glucose is obtained from the breakdown of carbohydrates (starches) and also can be manufactured from other large molecules such as amino acids (building blocks of proteins). The liver can store enough glucose to supply the brain (and other parts of the body) for up to four hours. After that amount of time, however, other sources of glucose have to be found.

Many other nutrients are required by the nervous system. Minerals, such as calcium, sodium, potassium and chlorine, are vital for generating the electrical impulses that travel along nerve cells. Phosphorous is present in a chemical messenger between neurons and also is essential for the processing of energy in cells.

Unfortunately, our bodies are not able to make all of the molecules that are needed for the nervous system and the rest of the body systems. These molecules must be taken in through food. Proteins, for example, provide important building blocks (amino acids) for several chemical messengers between neurons. Choline, a substance found in egg yolks and leafy vegetables, is the basis for the chemical messenger that carries signals to muscles. Essential molecules that are needed in small amounts by the body are called vitamins. Vitamins play key roles in many basic functions inside cells, including nerve cells, and throughout the body.

The "Nutrition Facts" label on packaged foods can be used to make better food choices. This label lists the amounts of nutrients present in grams or as a percentage of the recommended "Daily Value." Many teenagers eat foods that are high in fats and carbohydrates, and do not eat enough fruits, vegetables and dairy products or other sources of calcium. This activity allows students to examine their eating habits, and to calculate their intake of one nutrient (calcium) that frequently is neglected in the diets of American adolescents.

Links

This activity may be taught along with the following components of the Brain Chemistry unit.

Legacy of Lost Canyon chapter:
Discovery (also see science box page 12)

CONCEPTS

- Making good food choices can lead to better health.
- Some foods are good energy sources.
- Some foods contain chemicals that are essential for the functioning of cells.

OVERVIEW

This activity highlights the importance of good eating habits to overall health and to mental performance.

SCIENCE & MATH SKILLS

Observing, recording observations, organizing data, making decisions based on data

TIME

Preparation: 10 minutes
Class: 45–60 minutes

MATERIALS

Each student will need:

- copies of "Brain Food" and "Calculating Calcium" student pages
- notebook paper or science journal to create lists and charts

Each group of students will need:

- several "Nutrition Facts" labels cut from food packages

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Carbohydrates, a major source of energy, are found in fruits, vegetables, grains and flour. Fiber, starches and sugars all are carbohydrates. Most US students tend to eat too many snacks and prepared foods that are high in sugars, instead of choosing vegetables, breads and pasta that contain less sugar and more starches and fiber.

Fats are rich sources of energy. Cooking oils, lard, butter, margarine and shortening are almost pure fat. Foods that contain large amounts of fat include some red meats, dairy products, chocolate, cakes, cookies, fried snacks (chips, crackers, etc.) and nuts. Fatty foods should be eaten sparingly, because the body will store any unused energy as additional body fat. Fats from plants (like olive or canola oil) or fish generally are healthier than butter, fatty meat, lard or margarine.

Proteins are building blocks for the body. Muscles, hair, skin and nails are mostly protein, as is the flexible collagen network within bones. Proteins help carry out essential chemical reactions within every cell. The body can use protein as a source of energy. Meats, fish, poultry, eggs, low-fat dairy products, beans, peas and nuts are good sources of protein.

Vitamins are substances needed by the body in small amounts. Vitamin C is necessary for the development of connective tissue and helps prevent damage to cells. Vitamin A is important for vision. Eating a variety of fruits and vegetables every day helps ensure that the body has all of the vitamins it needs.

Minerals have a number of roles. Calcium, the most abundant mineral in the body, makes bones hard and is important in muscles and the nervous system. Good sources of calcium are low-fat dairy products, dark green leafy vegetables, tofu, sardines with bones and calcium-fortified juices and cereals.

Set-up

Have students bring in nutrition labels from food packages. Put a mixture of labels from different kinds of foods in plastic bags and place them in a central location. Begin with a discussion with the entire class. Following the discussion, students should work in small groups of 2–4.

Procedure

1. Have each student make a list of everything he or she ate during the past 24 hours (including all snacks).
2. When students have finished their lists, ask, *Did you think about getting enough food for your brain? How could we know if we have eaten the right things for our brains?*

Encourage students to think about aspects of nutrition that might influence the brain.

3. Ask, *Have you ever noticed if it makes a difference in your ability to concentrate in class or perform in other activities if you skip breakfast or lunch? Why do you think this might be so?* Mention that the brain needs many different kinds of nutrients to perform. These include sources of energy, building blocks for making chemical messengers and other kinds of molecules that the body cannot make on its own. Ask, *Where can the body get all of these different nutrients?*
4. Distribute a copy of the "Brain Food" page to each group. Point out the different food groups on the page and their role in the brain and nervous system. Have students identify the food group categories in which each of the items on their lists belongs. Some items may fall into more than one food category. Encourage students to discuss these within their groups in order to make a decision. For example, a large portion of lasagna might count as one serving from the bread/pasta group, one serving from the dairy group (cheese) and one serving from the meat group (ground beef or sausage).
5. Have each student make a chart with a column for each of the food groups. Students then should record in the appropriate column the foods they ate over the past 24 hours and the number of servings. Have students compare their totals to the recommended numbers of servings.
6. Ask, *How many of you had the recommended amounts of fruits, vegetables and dairy products? Did anyone exceed the recommendations for fats and sweets? How about breads and pastas?* Distribute the "Calculating Calcium" page, which focuses on calcium, an essential mineral for the transmission of messages in nerve cells, and a vital component of bones. Have students refer to their lists and identify any foods that they ate that are good sources of calcium. Next, have them calculate the number of milligrams of calcium that they included in their diet over the past 24 hours.
7. Ask students, *Is there room for improvement in your eating habits?* Have the Materials Managers collect a bag of nutrition labels from the materials table. Have each group read the labels and rank each of the foods from best to worst in terms of nutrients needed for brain function (protein, whole-grain carbohydrates, Vitamin C, Vitamin A, calcium, for example). Then have groups share their lists with the rest of the class.
8. Conclude by asking students to suggest simple ways in which they could make changes to improve their diets. Record their ideas. You may want to discuss the word "diet" with students. Even though it is frequently used to describe an eating program to promote weight-loss, "diet" also can mean the usual things that a person eats.

FOOD & THE BRAIN

- A child's brain grows rapidly before birth and for about two years after birth. Malnutrition during these periods can affect development of the nervous system.
- Only 53 % of US adults eat breakfast.
- Chocolate contains about 380 chemicals. Some of these are stimulants, which may make you feel more alert. Other chemicals in chocolate may affect the pathways of neurotransmitters related to feelings of well-being.
- Vitamin A deficiencies can lead to night blindness (inability to adjust from light to dark environments) and other vision problems. Vitamin A is found in yellow/orange vegetables, dairy products and beef liver.

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Brain Jogging

Here are more ideas for you and your students to explore.

- Encourage students to create or find recipes that include many nutrients needed by the brain. Share these with the class OR have a "Brain Food Day," and have students (or parents) bring different foods from school to share in class or prepare one or more of the students' recipes in class.

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Brain Food

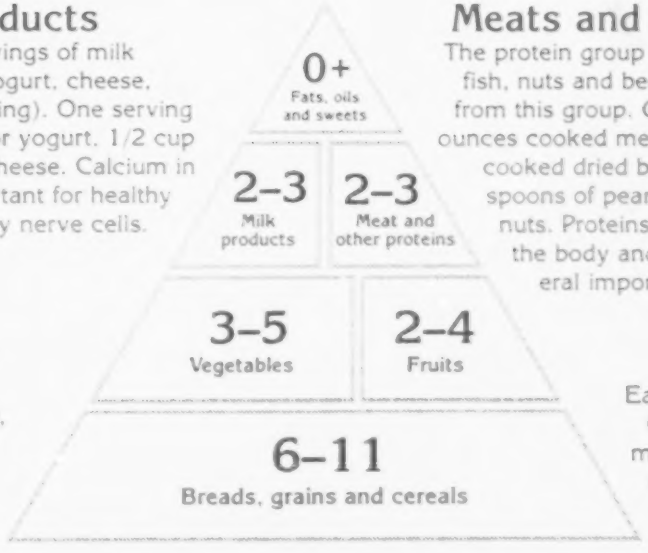
1. List all the foods you have eaten in the past 24 hours by meal (including snacks) on a separate sheet of paper.
2. Compare the foods you ate to the food groups shown in the pyramid below. Keep in mind that many foods combine items from two or more groups. The number of servings shown is what you should eat every day.
3. On another sheet of paper, make a chart with each food group shown in the pyramid. List the foods you ate under the appropriate food groups on the chart.
4. Compare the number of servings that you ate to the recommended amount. *How did you do?*

Fats, oils and sweets

Eat sparingly (found in candy, chocolate, fried foods, cakes, pies, ice cream, butter and cream).

Milk products

Choose 2–3 servings of milk products (milk, yogurt, cheese, cottage cheese, pudding). One serving equals 1 cup of milk or yogurt, 1/2 cup pudding or 2 slices of cheese. Calcium in dairy products is important for healthy bones and is needed by nerve cells.



Meats and other proteins

The protein group includes meat, chicken, fish, nuts and beans. Pick 2–3 servings from this group. One serving equals 2–3 ounces cooked meat, poultry or fish, 1 cup cooked dried beans, 2 eggs, 4 tablespoons of peanut butter or 2/3 cup of nuts. Proteins are found in all cells in the body and are used to make several important neurotransmitters.

Vegetables

Select 3–5 servings of vegetables. One serving equals 1 cup raw, leafy vegetables or 1/2 cup cooked vegetables (or 1/2 cup chopped raw), or 3/4 cup of vegetable juice.

Fruits

Eat 2–4 servings of fruit. One serving equals 1 medium apple, banana or orange, 1/2 cup cooked or canned fruit or 3/4 cup of fruit juice. Vitamins from fruits and vegetables are essential for all cells. Vitamin A, for example, is important for vision (thiamine).

Breads, grains and cereals

Have 6–11 servings of breads, grains, rice, potatoes, cereals, tortillas and pasta daily. One serving equals 1 slice bread, 1 tortilla, 1 cup of read-to-eat cereal, 1/2 cup cooked cereal, rice or macaroni, or 5–6 small crackers. Cakes, cookies, pies, french fries and chips also count as carbohydrates. Members of this food group provide energy and other nutrients, such as thiamin, which is necessary for muscle coordination.

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Calculating Calcium

SOURCES OF CALCIUM Dairy Foods	mg / serv. (approx.)
Milk (1 cup)	300 mg
Cheese (2 slices)	200 mg
Cottage cheese (1 cup)	140 mg
Yogurt without fruit (1 cup)	415 mg
Yogurt with fruit (1 cup)	315 mg
Ice cream or ice milk (1 cup)	150 mg
Frozen yogurt (1 cup)	200 mg
Pudding or custard (1 cup)	150 mg

SOURCES OF CALCIUM Non-Dairy or Combination Foods	mg / serv. (approx.)
Collard greens (1 cup)	357 mg
Sardines with bones (3 oz)	350 mg
Tofu (1/2 cup)	300 mg
Cheese pizza (1/4 of a 12 inch pizza)	250 mg
Macaroni and cheese (1 cup)	250 mg
Grilled cheese sandwich (1 sandwich)	250 mg
Lasagna (1 cup)	250 mg
Calcium-enriched orange juice (3/4 cup)	225 mg
Pancakes or waffles (2 waffles or 3 pancakes)	100 mg
Soup prepared with milk (1 cup)	150 mg
Calcium-enriched cereal (1 cup)	150 mg
Dry roasted almonds (1/4 cup)	100 mg
Chili con carne with beans (1 cup)	100 mg
Taco with cheese (1 taco)	100 mg
Cooked broccoli (1 cup)	90 mg
Tortillas (3)	80 mg
Scrambled, boiled or fried eggs (2 eggs)	80 mg
Baked beans (1/2 cup)	80 mg
Milk chocolate (1 1/2 ounce bar)	80 mg
Bread (1 slice)	40 mg

Source: <www.fda.gov>

1. Take a look at foods list you made for the "Healthy Choices" sheet. Refer to the "Sources of Calcium" lists above and to the right on this page and identify any calcium-rich foods on your list. Record these foods on the table below—along with the number of servings you ate. (Use a separate sheet of paper if necessary.)
2. Find the number of milligrams (mg) of calcium per serving for each of the foods you identified and record it on the table below. You may need to estimate the amount of calcium in some foods based on the ingredients or on similar foods. Multiply the number of servings by number of mg of calcium to find the total amount of calcium that you received with each food. Add the totals for each food to figure out how much calcium your body took in during the past 24 hours.
3. The recommended amount of calcium for teenagers is 1,200 milligrams per day. *How does this compare to your amount?*

Calcium-rich foods	Number of servings	Amount of calcium (mg)	Total
Total calcium in one day			

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Brain Choices

ACTIVITY 8

Background

The structure of the brains of all mammals is similar. Each consists of three basic regions—brainstem, cerebellum and cerebrum—with different functions. The cerebrum, which is responsible for thought, planning, memory, voluntary movement and the processing of most sensory information, is relatively larger and more complex in humans than in any other animal.

Information is stored and communicated in the brain as connections between nerve cells, known as neurons. Neurons receive incoming signals on branches called dendrites or on the cell body and transmit the signals as an electrical charge that travels along the cell membrane. In order for the message to reach another cell, the charge in the cell membrane triggers the release of special chemicals called neurotransmitters. These chemicals cross a minute water-filled gap, where they connect to a specific receptor. The process either stimulates or inhibits initiation of a new electrical signal within the receiving neuron.

Many substances can mimic or interfere with the action of neurotransmitters in the brain and nervous system. Examples include caffeine from coffee or cola drinks, nicotine in cigarettes, alcohol, chemical compounds in marijuana, LSD, cocaine and compounds in adhesives and sprays that are inhaled ("sniffed"). Abuse of some substances, such as cocaine, can lead to physical changes in the brain. These changes create physical cravings (addiction), because neurons in the brain have adapted to the presence of the drug.

Links

This activity may be taught along with the following components of the Brain Chemistry unit.

Legacy of Lost Canyon chapters:
Review science boxes throughout

Set-up

The first part of this activity is teacher directed and should be similar to the introduction of this Brain Chemistry unit in Activity 1. The second part should be conducted individually by students. Finally, students should share their products within small groups or with the class.

Procedure

1. Repeat some of the questions you used to introduce this unit. Ask, *What do you know about the brain? Does it have different regions? What is the brain made of?* Follow by asking students if they have answered any of the questions on the list

CONCEPTS

- The human brain is uniquely complex.
- Messages within the brain and nervous system are conducted by living cells—neurons.
- Drugs and other substances can interfere with or modify the transmission of messages between neurons.

OVERVIEW

Students will express what they have learned about brain chemistry by writing a persuasive letter.

SCIENCE & MATH SKILLS

Summarizing ideas, presenting results

TIME

Preparation: 5 minutes
Class: 20 minutes for class discussion; 45 minutes in class or at home to write letters; 30 minutes to share letters with class

MATERIALS

Each student will need:
- notebook paper

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they made at the beginning of the unit. If there are still unanswered questions, point out that neuroscience is one of the most exciting and rapidly expanding fields of biology. New information is being generated every day.

2. Tell students that they will have an opportunity to communicate what they have learned about the brain by writing a persuasive letter to an imaginary friend. The letter should be directed toward convincing the imaginary friend to not smoke, to not drink alcohol or to not use an illegal drug. The letter should include as much information about the brain as possible as well as describe how chemical substances can affect neurons.
3. Discuss appropriate formats for letters with students. Each letter should be at least one page long.
4. The next day, or at the end of the period, have students read their letters aloud within their groups or to the class.